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THE EFFECTS OF POLLUTION CONTROL ON THE NONFERROUS METALS INDUSTRIES

COPPER

Part II

Structure of the Industry

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CHARLES RIVER ASSOCIATES INCORPORATED · CAMBRIDGE, MASSACHUSETTS

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THE ECONOMIC EFFECTS OF POLLUTION CONTROLS ON THE NONFERROUS METALS INDUSTRY: COPPER

Prepared for
the Council on Environmental Quality

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PREFACE

This report on the economic effects of pollution controls on the copper industry has been organized into three parts comprised of eight chapters. The three parts can be read separately or in conjunction with one another. Part I summarizes the contents of the succeeding two parts, providing a broad profile of the copper industry and outlining the economic effects of pollution controls on the industry. The important points and conclusions of the full report are contained in the first part, with greater detail and analysis in the following two parts.

Part II comprises separate chapters on:

Trends in supply and the technology of production
Consumption
Structure of the industry
Prices
Government policies
The copper industry in the United States

Part III is our detailed analysis of the economic effects of imposing pollution controls on the copper industry.

Much of the information contained here was first published in Charles River Associates Incorporated, *An Economic Analysis of the Copper Industry* (Cambridge, Mass., 1970), which we prepared under contract with the General Services Administration. Data presented in this report if not otherwise attributed is taken from our GSA report.

PART II

Chapter 2

TRENDS IN SUPPLY AND THE TECHNOLOGY OF COPPER PRODUCTION

Introduction

Copper ores are mined principally in the United States, Canada, the Soviet Union, Chile, Peru, Zambia, Republic of the Congo, and Australia. World production of copper in 1970 was 6.9 million short tons, an increase of 51 percent over 1960 production. U.S. mine production was 1.7 million tons in 1970, an increase of 56 percent over 1960. In 1970, U.S. mine production amounted to 25 percent of world production and 30 percent of the non-communist world total. After the United States, the leading producing countries are the Soviet Union with 14.5 percent of world production, and Zambia with 11.2 percent.

NONCOMMUNIST WORLD COPPER PRODUCTION
(THOUSANDS OF SHORT TONS, COPPER CONTENT)

Country	1960	1962	1964	1966	1968	1970
United States	1,093	1,224	1,251	1,408	1,203	1,706
Zambia	635	620	710	687	755	765
Chile	587	646	685	701	726	747
Canada	439	465	487	508	633	674
Democratic Republic of the Congo	333	323	305	349	358	425
Noncommunist World	3,950	4,177	4,399	4,751	4,843	5,647

SOURCE: *Yearbook of the American Bureau of Metal Statistics*, 1967 and 1971 issues.

Domestic reserves of copper were reported in 1967 as 85.5 million tons of metal ore.[1] Principal commercial world reserves are reported as follows:

Country	Reserves (Millions Short Tons, Copper Content)
United States	85.5
Chile	59.3
Soviet Union	38.5
Zambia	30.0
Peru	24.6
Congo	20.0
Canada	10.0
Other	40.0
TOTAL	307.9

[1] *Mineral Facts and Problems*, U.S.D.I., Bureau of Mines Bulletin 650, 1970 Edition, p. 541.

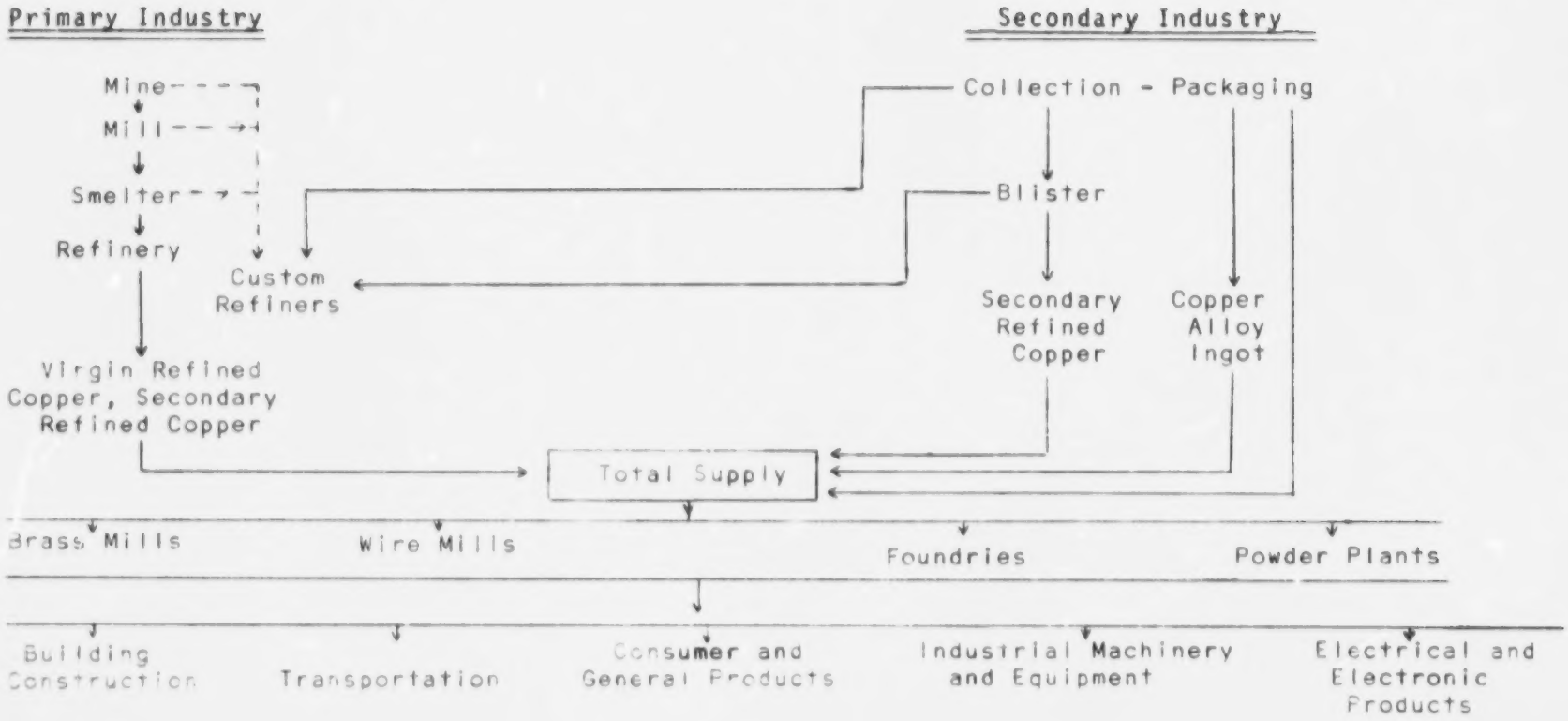
It appears from these data that known reserves are adequate for several decades at the current production rate.

The Primary and Secondary Industries

Copper ore is mined and concentrated and then smelted to produce "blister" copper, usually in the vicinity of the mine. The blister is refined to pure copper near the smelter or shipped to a refinery in the vicinity of a copper fabricating industry. The fabricators form the pure copper into wire, rod, tubing, sheet, castings and so forth for use in various industries. Copper thus produced is known as primary copper. A small proportion of primary copper is used in the production of alloy ingots (brass), but the main source of copper for ingots is used and scrap copper and alloy. Some scrap is also refined to produce secondary refined copper which is physically indistinguishable from primary refined copper. We shall refer, however, to a "primary industry" which depends on mine production as its main source of copper (although it refines a small proportion of scrap), and to a "secondary industry" which depends on brass and copper scrap as its raw material (although it also processes some mine production).

The stages in copper production are diagrammed in Figure 2-1. The primary industry, shown on the left, includes seven integrated producers in the United States and about 30 in the noncommunist world, but is dominated by a few integrated firms including Anaconda, Kennecott, and Phelps Dodge in the United States.

Figure 2-1
FLOWS OF COPPER PRODUCTS



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The primary copper industry is not fully integrated, but the mine, mill, and smelter production of nonintegrated or partially integrated firms is relatively unimportant. However, it is important to distinguish between "custom refiners" and the integrated primary producers. Custom refiners process scrap and purchase, or process, the output of "independent" mines, mills and smelters. The plant capacity of the major domestic custom smelter and refiner -- American Smelting and Refining Company -- is comparable to that of the major primary producers.

A very abbreviated sketch of the secondary copper industry appears on the right of Figure 2-1. The secondary industry begins with scrap collection and "packaging" -- sorting, grading, bailing, etc. of scrap. This phase of the industry is carried on by numerous scrap yards and scrap dealers. Some scrap goes directly to custom refiners (and to a lesser extent primary producers as well) for smelting and refining. A small quantity is smelted to blister copper by secondary producers and then refined by custom refiners, or by secondary producers. Part of the remaining scrap is used directly by fabricators and the rest is first processed into copper alloy ingot. A large number of firms is involved at each stage, and secondary markets appear to be highly competitive.

Figure 2-1 shows total copper supply as comprising primary refined copper and the various secondary copper products -- some types of scrap, copper alloy ingot and secondary refined copper. While primary and secondary refined copper can safely be regarded as perfect substitutes, this is not true of all secondary products. But

secondary copper does substitute for primary copper in the sense of displacing it and, in general, plays an important role in copper markets.

Geographic Distribution of World Copper Production

Table 2-2 shows mine production of copper by geographic areas for selected years over the period 1946-1970. The bulk of the noncommunist world's copper is, and has been for many years, mined in five countries: the United States, Chile, Zambia, Canada and the Republic of the Congo. Substantial quantities of copper are also mined in Peru, Australia, Japan and Mexico. Mine production in the United States has generally been about twice that of the next largest area.

During the 1960-1970 period the greatest rate of growth shown in the table is for "Other Africa" and results from a two-hundred percent increase in production in the Union of South Africa. In the same period the United States increased production by 56 percent and Canada by 54 percent. Europe increased production by 83 percent, mainly in Yugoslavia which is the only European country which can be regarded as a sizeable ore producer.

Asia increased production 70 percent, mainly in the Philippines, the largest Asian producer, whose output increased from 70,000 to 177,000 short tons. The 1970 output and share of world mine production for each of the seven largest producing countries was as follows:[1]

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[1]American Bureau of Metal Statistics, *Yearbook*.

Table 2-2

MINE PRODUCTION OF COPPER BY AREAS, 1946-1968

(Thousands s.t. Copper Content)

	1946	1950	1954	1956	1958	1960	1962	1964	1966	1968	1970
North America											
United States	604	915	841	1,114	990	1,093	1,224	1,251	1,408	1,203[1]	1,706
Canada	189	264	303	355	345	439	465	487	508	633	674
Other	77	88	77	77	86	80	58	64	89	75	75
Total	870	1,267	1,221	1,546	1,421	1,612	1,747	1,802	2,005	1,916	2,458
South America											
Chile	398	400	401	540	510	587	646	685	701	726	747
Peru	27	33	42	51	59	200	184	192	194	223	234
Other	10	6	4	5	3	10	19	25	31	24	23
Total	435	439	447	596	612	797	849	902	926	985	1,004
Africa											
Zambia	205	315	439	445	441	635	620	710	687	755	765
Republic of the Congo	159	194	247	275	262	333	323	305	349	358	425
Other	30	49	59	78	98	104	109	140	213	212	239
Total	394	558	745	798	801	1,072	1,052	1,155	1,249	1,325	1,429
Europe	98	128	104	107	121	122	163	169	162	189	223
Asia	44	111	154	191	213	229	248	259	291	333	386
Australia	20	19	45	54	79	118	119	110	116	112	152

[1]Estimated to take into account mine production normally smelted in the United States but which, because of the 1967, 1968 strike, was diverted to plants elsewhere and this was not reflected in ABMS returns.

SOURCE: *Yearbook*, American Bureau of Metal Statistics.

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	1970 Production (Thousands Short Tons)	Share of World Output (Percent)
United States	1,706	25
Soviet Union*	990	14
Zambia	764	11
Chile	747	11
Canada	674	10
R. of Congo	425	6
Philippines	177	3

*Reported as conjectural.

Table 2-3 shows mine, smelter and refined copper production in the major producing and consuming areas for 1969 and 1970. Comparing the figures for the separate stages of production indicates roughly whether a country is a producer or consumer. Usually copper is smelted where it is mined and refined where it is sold to fabricators. The U.S. mines and smelts approximately equal quantities but refines a significantly larger amount. Part of domestic refined output originates from scrap, part from imported blister. Canada mines rather more than it smelts as do Chile, Peru and the Philippines, all of which export ore to the United States.[1] (The Philippines have no smelter capacity.) The data suggest that Spain is a smelter and refiner, smelting twice as much as it mines and refining twice as much as it smelts. Belgium and the United Kingdom are refiners. The Republic of the Congo smelts as much as it mines, but

[1] *Minerals Yearbook 1969* "Copper," Table 41, p. 477.

Table 2-3
NONCOMMUNIST WORLD PRODUCTION OF COPPER 1969 AND 1970
(Thousands s.t. Copper Content)

Country	Mining Production		Smelter Production[1]		Refined Copper Production	
	1969	1970	1969	1970	1969	1970
United States	1535.0	1705.8	1567.8[2]	1620.2[2]	2242.0	2274.4
Canada	573.2	673.7	431.3	506.0	450.6	543.1
Mexico	72.9	67.3	63.3	65.4	62.9	60.3
Chile	758.5	747.0	712.8	707.2	499.2	508.5
Peru	219.1	233.7	185.6	194.4	34.7	39.6
Total America	3191.0	3458.0	2964.7	3097.2	3293.4	3430.3
Spain	20.9	21.6	43.6	44.2	83.8	91.0
W. Germany	1.7	1.4	441.1[3]	447.0[3]	443.2	447.3
Yugoslavia	90.0	100.1	105.7	118.8	90.4	98.4
Belgium	-	-	-	-	316.0	372.1
United Kingdom	-	-	-	-	218.5	227.3
Total Europe	216.9	222.5	745.0	765.9	1355.0	1438.3
Japan	133.5	131.6	584.0[2]	674.9[2]	693.6	777.1
Phillipines	144.9	176.7	-	-	-	-
Total Asia	353.6	386.1	621.7	712.5	726.9	812.5
R. Congo	399.3	424.9	401.1	425.1	200.9	209.7
R. South Africa	139.1	164.5	138.5	163.8	67.5	72.8
Zambia	792.9	764.8	775.5	756.4	664.9	636.0
Total Africa	1402.7	1428.5	1388.1	1419.8	957.9	944.9
Australia	135.4	151.7	128.1	122.2	152.8	157.9
Free World Totals as Reported	5299.6	5646.8	5847.6	6117.6	6486.0	6783.9
Soviet Sphere Total	1160.4[4]	1207.1[4]	1185.3[4]	1250.6[4]	1432.6[4]	1461.7[4]
World Total	6460.1	6853.9	7032.9	7368.2	7918.6	8245.6

[1]Effort has been made to eliminate secondary copper from this tabulation.

Footnotes continued on following page.

Table 2-3 (Continued)
NONCOMMUNIST WORLD PRODUCTION OF COPPER 1969 AND 1970

Footnotes continued from previous page.

[2]Excludes scrap processed by firms which also process primary copper.

[3]A considerable part of this production is derived from scrap.

[4]Conjectural

SOURCE: American Bureau of Metal Statistics, *Yearbook*, 1970.

refines only 50 percent of smelter production. Zambia smelts as much as it mines, and refines 85 percent of what it smelts.

Copper Production in the United States

Mining

In 1970, U.S. production of copper ore reached a record 1,705,800 short tons of recoverable copper content.[1] This represented an 11.1 percent increase over the previous year and a 25.8 percent increase since 1965, and accounted for 30 percent of total noncommunist production.[2,3] Excluding the strike of 1967 and the recuperatory period in 1968, domestic mine production has been steadily increasing during the past decade.

In 1965, 77 percent of the domestic mining production came from open-pit mines while the remainder was mined underground. By 1969 the proportion produced from open-pit mines had risen to 84 percent.[4] The average yield of copper for all domestic mines was 0.6 percent.[5] This percentage has generally been decreasing year-by-year. Recovery was 0.7 percent in 1965, 0.67 percent in 1966,

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[1]American Bureau of Metal Statistics (ABMS), *Yearbook, 1970*, p. 11.

[2]*Minerals Yearbook 1969*, p. 452.

[3]ABMS, *Yearbook, 1970*, p. 11.

[4]*Minerals Yearbook 1969*, p. 463.

[5]*Ibid.*, p. 452.

0.60 percent in 1968. The decreasing trend reflects two facts. First, high-grade ores are being depleted and are not being replaced by discoveries of similar quality. Second, since underground mines are usually the more costly to operate, their percentage yield of copper usually has to be greater than from open-pit. Although 16 percent of domestic production was obtained from underground mines in 1969, this represented only 12 percent of the domestic ore mined.

Smelting and Refining

Total U.S. smelter production in 1970 amounted to 1,737,000 short tons. Of this amount almost 92 percent was smelted from domestic ore, 6.7 percent from scrap, and 1.6 percent from foreign ore. Smelter production for the past eight years was as follows:

DOMESTIC SMELTER PRODUCTION
(Thousands of Short Tons)

	1963	1964	1965	1966	1967	1968	1969	1970
Total Smelted	1393	1418	1521	1580	930	1352	1678	1737
From Scrap	142	129	129	139	79	105	110	117
From Foreign Ore	42	38	35	34	22	31	33	28

SOURCE: ABMS, *Yearbook 1970*, p. 12.

Smelter capacity is best expressed in terms of charge capacity -- the quantity of concentrate input that a smelter can process. The quantity of copper it

can produce (output) is dependent on the charge capacity and on the percentage copper content of the charge which is usually in the range 20 to 30 percent. Capacities of Michigan smelters, however, are reported on an output basis. At the end of 1970, Michigan output capacity was 135,000 tons (annual) and input capacity for the other domestic smelters totalled 8,704,000 tons.[1] Assuming an average copper content of 20 to 25 percent for concentrate, the total domestic output capacity was between 1,876,000 and 2,311,000 tons. On the basis of this estimate, average plant utilization in 1970 was between 75 percent and 93 percent.

Total domestic refinery production in 1970 was 2,329,000 short tons.[2] Refining capacity was reported as 2,676,000 tons.[3] Thus indicated capacity utilization was 87 percent. Of the total refining capacity 2,308,000 tons or 86 percent was electrolytic tank capacity. Refining output for recent years was as follows:

REFINERY OUTPUT
(Thousands of Short Tons)

	1964	1965	1966	1967	1968	1969	1970
Primary Production	1646	1758	1768	1112	1418	1760	1820
Produced from Scrap[4]	350	445	491	407	417	499	509
Total Refined[5]	1996	2203	2259	1519	1835	2259	2329
Refined Electrolytically[6]		1901	1945	1331	1560	2133	

[1] ABMS, *Yearbook 1970*, p. 30.

[2] *Ibid.*, p. 16.

[3] *Ibid.*, p. 27.

[4] *Ibid.*, p. 17.

[5] ABMS, *Yearbook 1970*, p. 30.

[6] *Minerals Yearbook 1969*, p. 466.

Technology

Mining and Milling

The main ore is copper pyrites ($CuFeS_2$) but other sulfide ores are also mined. Copper is also mined as oxides (e.g. cuprite, Cu_2O_2), as a carbonate (malachite, which is similar to an oxide from the processing standpoint), and occasionally as silicates. In some areas, including especially Michigan and the Sudbury area of Ontario, copper is found as native metal some of which is sufficiently pure to require no smelting. However, sulfide ores predominate domestically and constitute about 90 percent of the world's production.[1] In the United States, the copper content of ores mined (excluding native copper) is generally in the range 0.4 to 1.2 percent, although outside the United States, particularly in Africa, the average grade of ores taken from some deposits is over 3 percent.[2]

The most important distinction in copper mining is between open-pit and underground operations, as average costs per ton of ore mined are generally lower for open-pit mines. In 1969, 84 percent of domestic mine production was from open-pit mines and 16 percent was mined underground.

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[1]W.H. Dennis, *Metallurgy of the Nonferrous Metals*, (London: Sir Isaac Pitman and Sons, Ltd., 1961, 2nd Edition), p. 78.

[2]A.D. McMahon, *Copper: A Materials Survey*, U.S. Department of the Interior, Bureau of Mines, IC8225 (Washington, D.C.: GPO, 1965), p. 43.

The ore is concentrated prior to smelting and usually prior to shipping from the mine area so as to avoid unnecessary transportation costs. It is first crushed and ground, and then a copper-rich portion is separated from "gangue" (unwanted material) by flotation or leaching. In flotation processes, water is added to the finely ground ore to form a slurry, and a flotation reagent is added. Air is then beaten into the mixture to create bubbles which rise to form a froth on the surface and carry the copper-rich material, "concentrate", with them. The concentrate contains 20-30 percent copper. Leaching processes employ a solvent, usually dilute sulfuric acid, which dissolves the copper-containing minerals. The liquid solution is then removed from the undissolved gangue and copper is extracted from it by electrolytic deposition. Sulfide ores can generally be concentrated by flotation, while oxide or mixed oxide-sulfiue ores usually must be concentrated by leaching or some combination of leaching and flotation.[1] In 1969, 94 percent of ore-produced copper was extracted by concentration, 5.0 percent was obtained by leaching, and the remainder was smelted without prior treatment.

Smelting

Smelting traditionally is comprised of three stages: roasting, "smelting," and converting. The roasting process removes moisture, preheats sulfide concentrates, and burns off any free sulfur. The resulting "calcines" of copper and other metals are then smelted, which consists

[1]McMahon, *op. cit.*, pp. 96-105.

in heating in reverberatory furnaces with a flux and with air. The flux forms a slag with iron, calcium, magnesium and aluminum present in the calcines and is removed. The resulting "matte" consists of cuprous sulfide and ferrous sulfide. The matte is transferred, molten, to converters in which it is treated with a siliceous flux and air. Iron and other impurities in the matte form a silicate slag and the cuprous sulfide is converted to copper, cuprous oxide, and SO_2. Finally, the copper and copper oxide are transferred to a holding furnace in which most of the oxide is converted to copper. The molten copper, which is about 98.5 percent pure, is cast in slabs known as "blister" copper or as anodes for shipment to a refinery.[1]

The roasting stage adjusts the properties of concentrates to the requirements of the reverberatory furnaces, which are not readily adjustable. Roasting is omitted in about one-half of U.S. smelters, where the concentrates do not vary greatly. In smelters receiving a variety of concentrates (especially custom smelters) roasting is essential.

There has recently been great interest in "flash" smelting in which the entire smelting operation is performed

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[1] Kenneth W. Nelson, "Nonferrous Metallurgical Operations," *Air Pollution*, Vol. III, 2nd Edition, Arthur Stern, ed. (New York: Academic Press, 1968), p. 173. See also Guy Bridgstock, "How to Limit SO_2 Emissions with the Flash Smelting Process," *Engineering and Mining Journal*, April 1971, p. 120. This article describes the flash process and its characteristics. A table lists commission dates and expected commissioning dates for nine installations in Japan, Romania, Turkey, India, and Australia.

as a single process. Among its advantages the flash process produces a sulfur dioxide (SO_2) stream having a concentration suited to conversion to sulfuric acid at relatively low cost.[1] It also requires less fuel than conventional smelting which makes it attractive in countries where energy is costly. Its disadvantages include quite rigid limitations on the extent to which the charge of concentrate may vary in its properties.

Although several flash furnaces have been built in foreign countries and several are currently under construction[2] it is not clear at this time that any will be built in the United States. Magma Copper Company is reported to have decided on a flash smelter to replace its reverberatory furnaces at San Manual, Arizona.[3] Anaconda was reported to be considering a flash furnace but is thought to have decided against it, possibly in favor of an electric furnace.[4]

It appears that, for the United States, electric furnaces hold more promise than the flash furnace. Where power is cheap they have the advantage that SO_2 in the furnace off-gas is less diluted than in the conventional process and therefore more easily extracted. Inspiration Consolidated Copper is reported to have decided on an

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[1] *Ibid.*

[2] Bridgstock, *op. cit.*

[3] "Pressures build for more sulfur control," *Metals Week*, June 21, 1971, p. 25.

[4] *Ibid.*, p. 24.

electric furnace to replace its reverberatories at Miami, Arizona;[1] and Cities Service is reported as planning to replace its reverberatory at Copperhill, Tennessee with an electric furnace.[2]

For the future, there is the possibility of pyrometallurgical smelting being replaced by hydrometallurgical processes. Anaconda is currently operating a pilot plant using a hydrometallurgical process designed to produce elemental sulfur (so avoiding SO_2 emissions) and which is reported to have the possibility of producing copper at lower cost than the conventional process.[3]

Refining

Approximately 90 percent of primary copper produced domestically is electrolytically refined, about 7 percent is fire refined. Lake copper (native metal) accounts for the remainder.[4]

Reverberatory furnaces are generally used for fire refining. Blister copper is first melted with quartz to slag off any remaining iron and air is forced through the bath to remove any SO_2 and to volatilize any arsenic or antimony that remains. Next charcoal or coke is spread on the molten copper and green wooden poles are introduced. The decomposition of the wood removes oxygen from the copper oxide and leaves an oxygen content of from 0.03 to 0.06 percent at which point the

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[1] *Ibid.*, p. 26.

[2] *Ibid.*

[3] *Ibid.*, p. 24.

[4] American Metal Market, *Metal Statistics, 1969* (New York: American Metal Market, 1968), p. 103.

refined copper is cast. Methods are available for removing the remaining oxygen if desired.

In electrolytic refining blister copper anodes and cathodes of thin sheets of pure copper, are placed in a tank containing a dilute solution of copper sulfate and sulfuric acid. A low voltage current is passed between the cathodes and anodes causing copper to dissolve from the anodes and pure copper to deposit on the cathodes. Impurities in the anode either dissolve or sink to the bottom of the tank as a sludge known as anode mud. The cathodes are melted and cast into standard shapes for shipping to fabricators. The anode mud, depending on the origin of the copper ore, may be rich in precious metals -- gold, silver, platinum, palladium, selenium, and tellurium.

Chapter 3
CONSUMPTION OF COPPER

Trends in Total Consumption

Table 3-1 presents data on copper consumption for the United States and other major consuming nations for the 1959-1970 period. The table shows that the United States is the largest consumer, consuming in 1970 about 1.8 million of 7.3 million ton total. Japan, the Soviet Union, and West Germany are the next largest consumers, each consuming about half the U.S. amount. The rate of increase in Japan's annual consumption is notable, with annual consumption more than tripling in the 1959-1970 period compared to a 38 percent rise in the United States and a 67 percent increase for the world in the same period.

Figure 3-1 shows both the U.S. copper consumption and the U.S. index of durable manufactures for the 1947-1970 period. There is no apparent trend in copper consumption over the period 1947-1960, although, in the same period, the index of durable manufactures increased

Table 3-1

COPPER CONSUMPTION OF THE WORLD

(In tons of 2,000 lb.)

Country	1959	1963	1966	1969	1970
United States	1,312,300	1,579,500	2,239,800	1,913,700	1,816,700
Of which secondary	121,500	131,300	182,400	198,500	180,200
Canada	130,000	169,800	262,600	226,281	237,837
Total America	1,543,527	1,852,785	2,641,475	2,280,572	2,184,413
Belgium	75,716	73,472	114,190	125,583	134,976
France	200,000	275,900	321,100	369,000	364,500
Germany, Federal Republic	484,700	534,500	540,800	728,200	289,100
Italy	123,900	248,400	204,700	259,000	290,000
Netherlands	34,628	33,021	55,046	45,586	100,957
Sweden	82,900	82,000	80,000	88,000	90,000
United Kingdom	536,300	615,100	653,100	602,800	604,300
Yugoslavia	39,500	55,000	60,500	96,700	101,100
Total Europe	1,710,409	2,079,467	2,215,720	2,527,610	2,700,015
Japan	241,400	338,500	531,900	888,400	903,800
Total Asia	301,198	423,874	603,010	943,455	956,308
Africa	26,300	41,800	40,300	36,000	44,700
Australia	63,500	79,431	104,748	94,405	105,044
Free World Total, as reported	3,644,934	4,477,357	5,605,253	5,882,042	5,990,480
U.S.S.R.*	553,400	635,000	720,000	842,000	893,000
Soviet Sphere Countries in Europe & Asia	170,800	215,000	290,000	369,000	419,000
Soviet Sphere Total	724,200	850,000	1,010,000	1,211,000	1,312,000
World Total	4,369,132	5,327,357	6,615,253	7,093,042	7,302,480

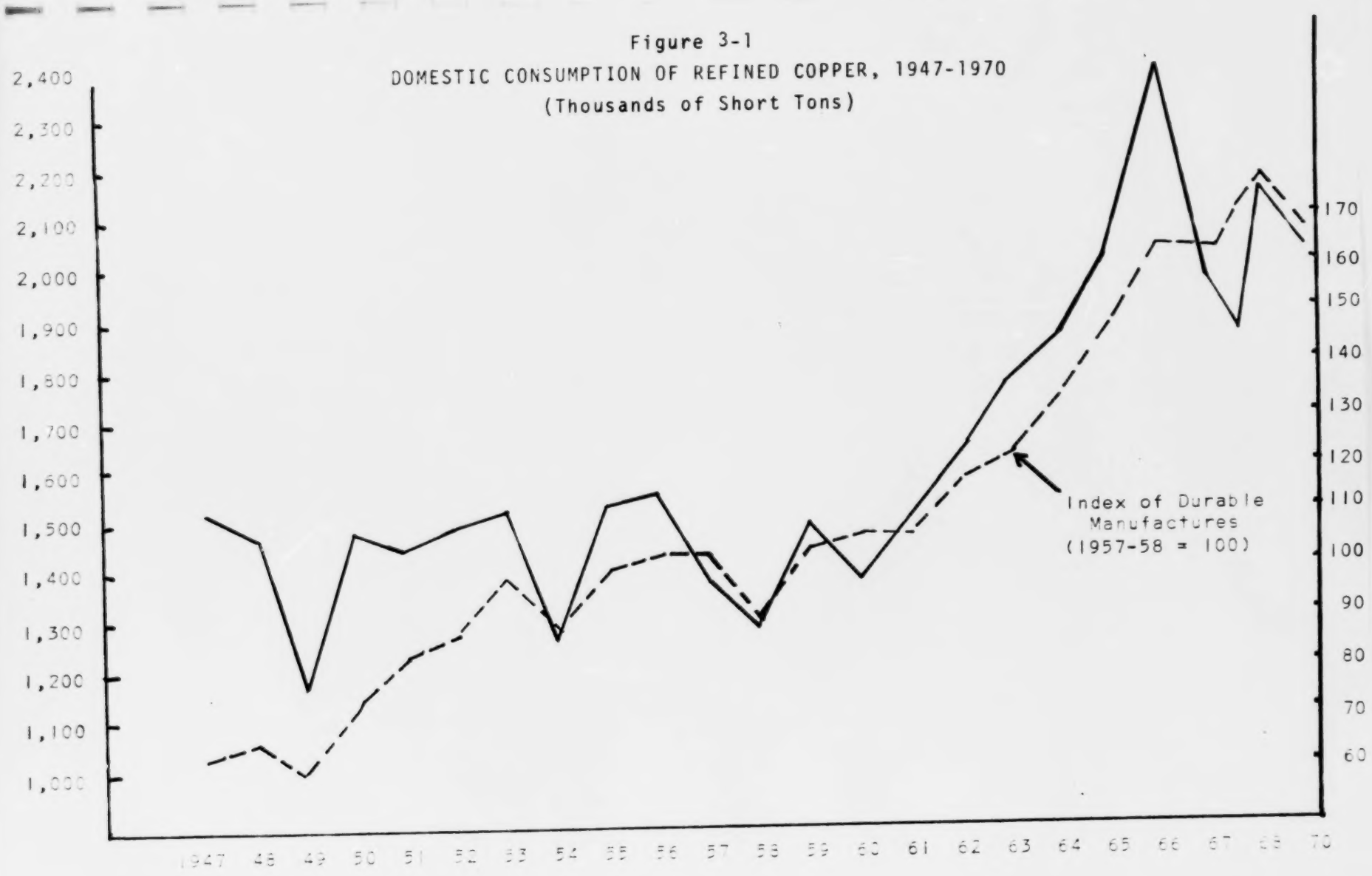
SOURCE: ABMS, *Yearbook*, 1971. The source cautions that in the computation of the above table there is absence of uniformity of method and totals of consumption as shown in it should be compared with totals of production, as given in other tables, in none but a cautious way. Total includes secondary where shown, also a quantity not possible to estimate in some countries.

* Conjectural

Figure 3-1

DOMESTIC CONSUMPTION OF REFINED COPPER, 1947-1970

(Thousands of Short Tons)



SOURCES: Copper Development Association, *Copper Supply and Consumption;* Copper Quarterly Industry Report, April 1971.

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from 64.3 to 105.6. The major discrepancy between the index and copper consumption occurs in the years 1947-1953; thereafter, copper consumption follows the index of durable manufactures fairly closely. Copper consumption and the level of durable manufactures production clearly increased rapidly after 1960, but have declined in the past two years.

International Trade Patterns

The major markets for ore are Europe and, secondarily, Japan. The United States has generally imported some ore, but the quantity has been small relative to both U.S. production and world trade in ore. Both the United States and Europe import substantial quantities of blister. Europe is the major market for copper produced in Africa.

Table 3-3 shows U.S. net imports of primary copper products and scrap and copper consumption for the period 1951-1970. The United States has generally been a net importer of ore, concentrate, matte and blister, a net exporter of refined copper and scrap, and on balance a small net importer. Net imports have averaged 12 percent of copper consumption, and have ranged from 4.5 percent to 21.9 percent with the higher figure occurring in the Korean War[1] period. U.S. imports of blister have come primarily from Chile and secondarily from Peru.

[1]The consumption figures used in Table 3-1 are suspected of being inacurrate and may overestimate actual consumption by a considerable margin. They are used for consistency with the other data in the table which comes from the same source. However, other data sources suggest that imports may have constituted a much higher percentage of domestic consumption.

Table 3-4 presents data on domestic shipments and net imports of semifabricated products. Since 1954, the United States has been a net importer of mill products, but these have been only a small part of consumption.

Copper Products

Fabricators obtain their copper inputs in three general forms: refined copper, scrap, and copper alloy ingots. Table 2-2 shows fabricators' consumption of refined copper, scrap, and alloy in 1969 and 1970. Wire mills and brass mills together constitute over 90 percent of the market for refined copper, the former using exclusively refined copper. Foundries, on the other hand, rely on scrap and allow ingot.

While these are distinct products (as described below), for the purposes of this study fabricators can be regarded as simply having a demand for "copper" which can be filled by several physically distinct products, each of which can be substituted for another on the margin.

Refined Copper

Refined copper is broadly divisible into two categories--electrolytic copper and fire refined copper. Fire refined copper is generally slightly less pure than electrolytic copper and cannot be used in applications which require high electrical conductivity; in particular,

Table 3-2

UNITED STATES NET IMPORTS AND TOTAL COPPER CONSUMPTION 1951-1970[1]

(Thousands s.t. Copper Content)

Year	Ore, Concentrate & Matte	Blister	Scrap	Refined	Total Net Imports	Total Copper Consumption	Net Imports as % of Consumption
1951	103	142	-1.1	105.7	349.6	2239	15.6
1952	105	162	-1.5	172.9	438.4	2262	19.4
1953	120	273	-43.6	163.2	512.6	2343	21.9
1954	118	255	-136.0	-0.9	236.1	2060	11.5
1955	114	252	-43.3	2.5	325.2	2419	13.4
1956	110	278	-52.3	-31.0	301.7	2365	12.8
1957	110	300	-87.9	-184.3	137.8	2106	6.5
1958	83	267	-30.3	-257.1	62.6	1975	3.2
1959	81	267	-22.1	55.0	380.9	2319	16.4
1960	78	290	-145.6	-292.4	-70.0	2079	-3.4
1961	47	335	-111.4	-369.1	-98.5	2170	-4.5
1962	43	330	-31.1	-238.7	103.2	2361	4.4
1963	48	368	-35.0	-193.4	187.6	2566	7.3
1964	51	385	-88.7	-179.0	168.3	2775	6.1
1965	26	328	-62.6	-193.5	97.9	2995	3.3
1966	41	349	-18.1	-117.0	254.9	3369	7.6
1967	-6	248	-45.1	168.7	365.6	2850	12.8
1968	-37	255	-76.6	149.3	290.7	2814	10.3
1969	38	234	-46.9	-83.8	141.3	3166	4.5
1970	-29[2]	216[2]	-79.1	-89.9	18.0[2]	2927	0.7[2]

[1]The copper content of ore and concentrate is a small percentage of the weight of these materials. The data are in terms of weight of recoverable copper, not gross tonnages.

[2]Preliminary

SOURCE: Copper Development Association, *Copper Supply and Consumption, 1951-1970.*

Table 3-3
DOMESTIC SHIPMENTS AND NET IMPORTS OF SEMIFABRICATED PRODUCTS, 1951-1970
(Millions Pounds Contained Copper)

Year	Shipments of Mill Products	Net Imports of Mill Products
1951	4951	-26
1952	4922	-7
1953	5032	-17
1954	4235	9
1955	5159	29
1956	4909	38
1957	4467	39
1958	4147	104
1959	4903	157
1960	4372	133
1961	4492	66
1962	4913	67
1963	5154	73
1964	5852	126
1965	6221	116
1966	7013	216
1967	5967	161
1968	6059	237
1969	6659	111
1970 (preliminary)	5763	123

SOURCE: Copper Development Association, *Copper Supply and Consumption, 1951-1970.*

Table 3-4

CONSUMPTION OF COPPER PRODUCTS BY FABRICATORS (1969 to 1970[P])

Fabricator	Refined (000 s.t. Cu Content)	Scrap (000 s.t. Cu Content)	Alloy Ingot[2] (000 s.t. Cu Content)	Total (000 s.t. Cu Content)
Wire Mills				
1969	1295.0[1]	--	--	1295.0
1970[P]	1338.0	--	--	1338.0
Brass Mills				
1969	799.1	516.6	5.9	1321.6
1970[P]	660.0	446.0	5.7	111.7
Foundries				
1969	23.8	147.4	255.3	426.5
1970[P]	23.7	128.7	211.9	364.3
Powder Plants				
1969	9.8	16.5	6.3	32.6
1970[P]	6.5	12.2	3.8	22.5
Other				
1969	10.4	50.2	38.9	99.5
1970[P]	5.8	61.1	24.2	91.1
Total				
1969	2138.1	730.7	306.4	3175.2[3]
1970[P]	2034.0	648.0	245.6	2927.6[3]

SOURCE: CDA '70 Copper Development Association, *Copper Supply and Consumption*, 1951-70.

[1]Wire mills consume refined copper only.

[2]Estimated Cu content. Between 88 and 95 percent of the total weight of Cu alloy ingot production is equal to the total Cu content used by ingot makers. All the Cu content weights in this column have been estimated by multiplying reported metal weights by 0.91 and 0.95 for 1969 and 1970, respectively and 0.88 for 1960.

[3]These totals vary from total Cu consumption data because of the estimations explained in footnote 2.

wire mills usually cannot substitute fire refined copper for electrolytic copper. Most electrolytic copper is sold to wire mills and most fire refined copper is sold to foundries and brass mills, but foundries and brass mills can use electrolytic copper (which is slightly more expensive) and high conductivity fire refined copper (HCFR) can be used at wire mills in place of electrolytic copper.

Both electrolytic and fire refined copper are sold in (approximately) standard shapes--wire bars, cathodes, ingots, ingot bars, cakes, slabs and billets. The shapes are largely determined by the requirements of the fabricators' equipment. Wire mills use the various shapes besides wire bars in roughly equal proportions.

Scrap

Scrap is divisible into old scrap and new scrap: scrap can be broadly classified into "low grade," "intermediate grade," and "high grade" material. Low grade material is recovered as refined copper by primary and secondary producers. Intermediate grade material is composed of alloy copper products. If the material is well sorted and the composition is known, it may be used directly by fabricators, especially by foundries. Otherwise it will usually be made into copper alloy ingot. High grade scrap, which is very nearly pure copper, may either be refined or used by fabricators as a substitute for refined copper.

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[1]Theodore Gruen, "Where Scrap Fits In," in Robert H. Lesemann, ed. "Market Guide--Copper," *E&MJ Metal and Mineral Markets* (now *Metals Week*) October 25, 1965, p. 37.

It is important to note that secondary refined copper is physically equivalent to a corresponding grade of primary refined copper. The term "secondary" means only that the copper was recovered from scrap rather than copper ore. Furthermore, secondary refined copper is not recovered exclusively by "secondary producers." Primary producers process some scrap, and most secondary refined copper is produced by custom refiners.

Copper Alloy Ingot

Copper alloy ingot, as the term implies consists of alloys of copper and other metals. Standard alloy categories have been established--such as "yellow brass" and "85-5-5-5"--but individual producers may market distinctive types. Copper alloy ingots are primarily sold to foundries.

Copper alloy ingot is used by fabricators as a convenient way of arriving at a fabricated product made of a particular alloy. Rather than purchasing pure constituent metals, making the alloy and then fabricating it, a fabricator may find it convenient simply to purchase one of the many types of copper alloy ingots. These are convenient to supply, as alloy ingot is generally recovered from scrap in which copper is already alloyed with one or more of the desired constituents. Producing an alloy from an alloy generally requires only melting, testing and some dilution.

End Uses of Copper

Table 3-5 shows domestic copper consumption by end use.[1] The data are graphed in Figure 3-2. The data show that the electrical and electronic products industries and building construction industries, the traditional major consumers of copper, are being overtaken by the consumer and general products industry, although the latter has fallen off somewhat in 1970. It is also worth noting that while copper consumption by the electrical and electronics industry grew by 7 percent per year from 1960-1967 (the second fastest growing copper end use sector), aluminum consumption by the same industry grew by 10 percent per year in the same period.

Table 3-6 shows U.S. consumption of semifabricated products by type of final user for 1958 (the only year for which such data are available). Both bare wire and insulated wire and cable are predominantly consumed in the manufacture of electrical equipment--power transmission lines, motors, generators, household appliances, etc. Consumption of brass mill products and castings are distributed much more evenly across user industries, although the largest single user in each case is fabricated metal products--hardware, plumbing fixtures, valves, etc. Two industries--fabricated metal products and electrical equipment--each accounted for approximately one-third of total consumption in 1958.

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[1]These consumption figures exceed the ABMS consumption figures shown earlier because they include consumption of secondary copper refined by secondary refiners--chiefly alloy ingot and scrap sold directly to fabricators.

Table 3-5

DOMESTIC COPPER CONSUMPTION BY INDUSTRIES 1960-1970
(Thousands of Short Tons)

Year	Net Copper Content at Input	Building Con-struc-tion	Trans-porta-tion	Consumer & General Prod.	Indus. Mach. & Equip.	Electrical & Elec-tronic Prod.	Total
1960	0.898	430	264	308	406	556	1964
1961	0.894	482	266	320	399	540	2007
1962	0.897	559	304	344	434	562	2203
1963	0.900	583	317	358	455	606	2319
1964	0.902	677	359	423	502	679	2640
1965	0.900	702	387	461	513	737	2800
1966	0.899	713	395	650	548	846	3152
1967	0.903	577	305	675	433	704	2694
1968	0.890	559	344	659	426	708	2696
1969	0.888	630	367	695	469	797	2958
1970[p]	0.909	574	303	546	439	758	2620

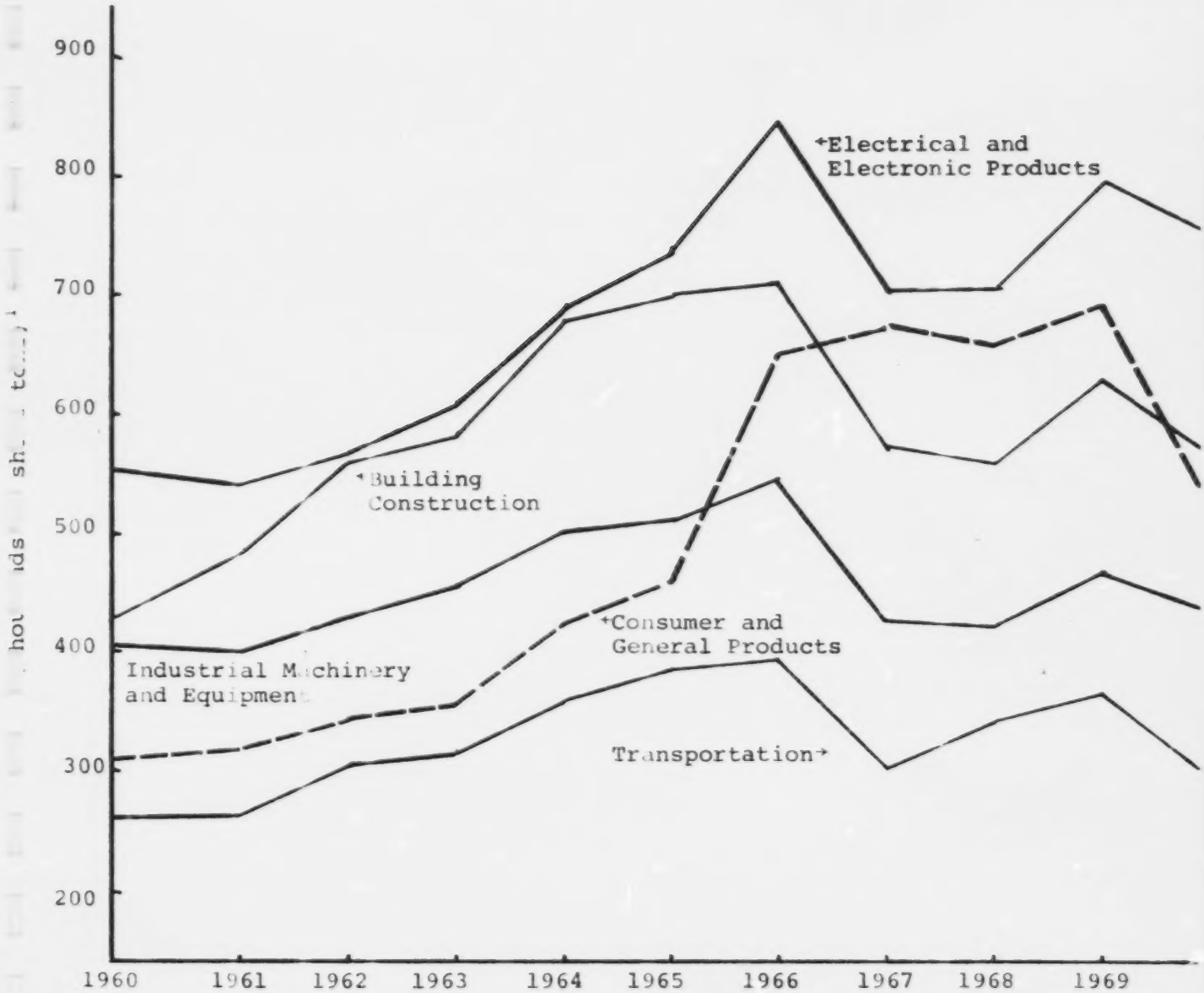
SOURCE: CDA, 1970 Copper Development Association, *Copper Supply and Consumption*, 1951-1970.

[1]Estimated Copper content. Source data are given in metal weight, including alloys, etc. Estimates for each year have been multiplied by $\frac{\text{wt. copper content of inputs}}{\text{total metal wt. of inputs}}$.

p = preliminary.

Figure 3-2

Domestic Copper Consumption by Industry
1960 - 1970



[1] Copper content estimates based on estimating procedure explained in Table 3-4.

Table 3-6

END USES OF SEMIFABRICATED COPPER PRODUCTS, 1958

(Millions of Pounds)

Consuming Industry	Bare Wire	Insulated Wire and Cable	Other Mill Products	Castings[1]	Total	% of Total Consumption
Ordinances and Accessories	[2]	2.9[2]	40.4	0.1	45.4	2.5
Fabricated Metal Products	6.8	2.8	474.0	90.7	574.4	31.9
Machinery, except Electrical	7.5	16.9	142.7	71.0	238.8	13.3
Electrical Equipment	176.6	205.4	224.1	22.7	628.8	34.9
Transportation Equipment	4.4	20.8	189.3	13.2	227.6	12.6
Instruments and Related Products	2.0	6.8	27.3	15.5	51.6	2.9
Miscellaneous Manufactures	---	--	36.2	0.1	37.0	2.1
Total: Metal Fabricating Industries[3]	192.3	257.6	1,132.0	214.7	1,801.5	100.0

[1]Excludes castings produced and consumed in same establishment.

[2]Bare wire included with insulated wire and cable.

[3]Metal fabricating industries include establishments whose primary activity is manufacturing products fabricated beyond metal mill or rolling level.

SOURCE: A.T. McWhan, *Copper: A Materials Survey*, U.S. Department of the Interior, Bureau of Mines, IC-8205 (Washington, D.C.: G.P.O., 1965), p. 24.

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Substitution for Copper

Short-Run and Long-Run Substitution

Short-run substitution for copper can take place whenever an alternative material can be used without requiring major alterations in fixed plant and equipment, or changes in product design. The major instances of this sort of substitution are probably to be found in residential and nonresidential construction. For example, the leading substitutes for copper drainage pipe are plastic and cast iron pipe. Copper pipe is apparently preferred on technical grounds, but if the price becomes too high or copper is simply unavailable, contractors can readily use plastic or cast iron. Each substitution is short run in the sense of requiring no investment and the effects of a change in price probably occur rapidly.

Short-run substitution can also take place through variations in the copper content of alloy semifabricated products. That is, a consumer who normally uses semis of pure copper or alloys with a very high copper content might switch to alloys with a lower copper content when prices are high. There are also very probably many ways in which the quantity of copper used per unit of output can be reduced.

The basic issues involved in long-run substitution are clearly indicated in a paper prepared by the Anglo-American Corporation and Roan Selection Trust, both of which are major copper producers in Zambia:

> Substitution is largely a question of the long term comparative costs of materials that technically can replace copper. The dilemma that the manufacturer often finds himself in is that he does not want to scrap his existing investment in copper fabricating facilities, but at the same time he knows that he would be correct in doing so if he knew that the price of copper was going to remain at uncompetitive levels in the long term.[1]

Substitution for copper is, in this statement, presented explicitly as an investment decision, and it is reasonable to suppose that such decisions depend on the prices which are expected to prevail over several years.

The reason why long-run substitution is a distinct issue is simply the fact that the use of a particular material often may require specialized equipment or may constrain product design. The defining characteristic of long-run substitution is the need for investment. This, in turn, gives rise to the view of substitution as a once-and-for-all event. Thus, if the price of copper rises high enough, and is expected to remain high, long-run substitution takes place. A fall in the price of copper to its initial level will not generate an immediate return to copper.

As well as the explicit investment required for long-run substition to take place there are also delays to substitution, due to the requirement for research and development before substitutions are

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[1] "Marketing of Primary and Secondary Copper," *Mining Magazine*, Volume 117, No. 4 (October, 1967).

technically feasible. This is, in a sense, a type of investment delay. A somewhat different kind of delay occurs when a technically feasible substitution is hindered by institutional barriers, such as building codes, that take time to revise.

Electrical and Electronic End Uses

Sales of aluminum to the electrical and electronics products industry have been growing more rapidly than sales of copper. This is the area in which major substitution against copper is most clearly occurring. Aluminum has been rapidly displacing copper in many electrical applications, attributable partly to the high and rising price of copper during much of the past fifteen years. Aluminum's principal advantages in this market are its ductility, lightness, high strength-to-weight ratio, and conductivity (aluminum is twice as conductive per pound as copper). Aluminum's principal disadvantage is that it corrodes in closed, moist environments. As Table 3-7 shows, between 1958 and 1969, U.S. shipments of aluminum wire products increased over 200 percent from 135,000 tons to 410,000 tons, while shipments of copper wire products increased only 80 percent from 708,000 to 1,294,000 tons.

The major use for aluminum in the electrical market is in power transmission and distribution. This use takes two-thirds of the aluminum shipped to the electrical market. It is estimated that 90 percent of overhead distribution systems are aluminum.[1]

Plastic-insulated aluminum cable is now being studied by Bell Laboratories as a copper substitute for telephone cable. Facilities at Western Electric produced 100 million feet of aluminum conductor in 1967 and were expected to

[1] *Metals Week*, October 14, 1968.

Table 3-7

U.S. SHIPMENTS OF ALUMINUM AND OF COPPER WIRE PRODUCTS, 1958-1969
(Thousands of Short Tons)

	Aluminum				Copper			
Year	Wire, bare conductor & iron	ACSR & aluminum cable	Wire & cable insulated or covered	Total	Bare wire	Insulated communication wire	Other insulated wire	Total
1958	22	87	26	135		708		708
1959	32	98	30	161		793		793
1960	28	92	30	149	89	191	481	761
1961	26	116	34	177	87	180	511	777
1962	28	127	38	193	82	185	551	818
1963	29	136	45	210	86	222	548	856
1964	22	155	52	228	101	260	636	997
1965	41	215	65	321	103	270	716	1089
1966	52	254	83	388	135	323	790	1247
1967	49	253	87	389	117	320	741	1178
1968	50	246	107	403	102	267	812	1182
1969	47	238	125	410	110	358	826	1294

Sources: U.S. Bureau of Census, *1963 Census of Manufactures, Industry Statistics.*

U.S. Bureau of Census, *Current Industrial Reports, 1964-1967*: Copper BDSAF-84, Aluminum M33-2.

U.S. Bureau of Census, "Quarterly Industrial Report," April, 1970: Copper.

The Aluminum Assoc., "Aluminum Statistical Review, 1969."

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increase production rapidly.[1] Cable television and community antenna television systems (CATV) also use aluminum cable.

Aluminum has been replacing copper in recent years in the production of wire for home electrical conductors. Between 1964 and 1967 aluminum consumption in electrical wire grew from 5,000 to 21,000 short tons, while copper consumption in electrical wire declined from 225,000 to 220,000 tons.

A number of possibilities exist for further displacement of copper by aluminum in electrical and communications equipment. Aluminum may have the potential to displace a substantial percentage of copper's total market in these applications, particularly in insulated underground residential distribution, insulated overhead wire, and telephone cable.

A possible major area of substitution of aluminum for copper is in the transportation industry. A number of auto manufacturers have been considering replacing copper radiators with aluminum radiators. If this occurs, it would reduce copper sales by as much as 160 million pounds per year (assuming 16 pounds per radiator and 10 million radiators per year.) An aluminum radiator would weigh about half as much as a copper radiator, which averages about 16 pounds, and the metal would cost about 20 percent less for material. In an attempt to penetrate the radiator market, Alcan has recently introduced a new epoxy repair system. However, auto industry officials cite workman

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[1] *Wire and Wire Products*, July, 1967.

inexperience with this process, as well as the cost of converting radiator fabricating facilities, as barriers to the widespread displacement of copper radiators.[1]

Chapter 4
STRUCTURE OF THE COPPER INDUSTRY

This chapter examines the structure of the copper industry in terms of concentration in mining, smelting, refining, and fabricating, the extent of vertical integration, the organization of physical distribution and the implications of the industry's structure for the possibility of entry to the industry. While emphasis is placed on the domestic industry the structure of the industry in the noncommunist world is also discussed.

Concentration

Table 4-1 presents concentration data for the domestic refined copper industry in 1970. The industry is clearly very concentrated. The five largest refiners hold approximately 90 percent of domestic capacity, while the remaining 10 percent is distributed among five firms. Concentration ratios based on value added are 90 percent,

Table 4-1

CONCENTRATION IN THE DOMESTIC
REFINED COPPER INDUSTRY, 1970
(Thousands of Short Tons)

	Domestic Mine Prod.		Smelter Capacity		Refinery Capacity[1]	
	Copper Content	% U.S.	Charge/ year	% U.S.	Refined Copper/yr.	% U.S.
Phelps Dodge	313.6	19.3	2075	22.7	620	23.2
Kennecott[2]	518.9	31.9	2220	24.3	565	21.1
ASARCO[3]	72.5	4.5	2136	23.3	642	24.0
Anaconda[4]	242.1	14.9	1000	10.9	340	12.7
Amax[5]	-	-	180	2.0	260	9.7
Subtotal	1147.1	60.6	7611	83.2	2427	90.7
Copper Range[6]	67.8	4.2	300	3.3	90	3.4
Inspiration Consolidated	65.9	4.1	450	4.9	70	2.6
Calumet & Hecla	-	-	100[8]	1.1	30	1.1
Cerro Corp.	-	-	-	-	44	1.6
Quincy Mining	-	-	50[8]	0.5	15	0.6
Magma	112.3	6.9	553	6.0	-	-
Cities Services	43.7	2.7	90	1.0	-	-
Total	1436.8	78.5	9154	100.0	2676	100.0

[1]Includes fire and electrolytic refinery capacity.

[2]Kennecott Copper Corporation and Kennecott Refining Corporation.

[3]American Smelting and Refining Company.

[4]Includes International Smelting and Refining, a wholly-owned Anaconda subsidiary.

[5]American Metal Climax.

[6]Refinery capacity is held by White Pine Copper Company, a wholly-owned subsidiary of Copper Range.

[7]Lewin-Mathis Division of Cerro Corporation.

[8]Idle.

SOURCE: American Bureau of Metals Statistics, *Yearbook*, 1970.

84 percent, and 90 percent respectively for 1958, 1963 and 1966, indicating a fairly constant degree of concentration.[1] The production and capacity data presented in Table 4-1 exclude the foreign holdings of U.S. firms, some of which are substantial.

The two major custom refiners--ASARCO and AMAX--appear among the five largest domestic refiners. Much of the refinery capacity of these and other custom refiners is used to process copper scrap rather than primary blister copper.[2] The major primary producers are Anaconda, Kennecott and Phelps Dodge. Excluding all of the capacity held by the custom refiners, these three firms have approximately 90 percent of domestic "primary" copper capacity.[3]

In addition to refined copper, there are secondary sources of supply, chiefly of copper alloy ingot and scrap used directly by fabricators. Concentration data on this "secondary" industry, are scarce but the available evidence is that these markets are unconcentrated. For example, one source states:

> . . . The industry consists of several thousand collectors and dealers, several hundred foundries, about eighty ingot makers and secondary smelters, around fifty brass

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[1] SIC Code 3312, Refined Copper made by Primary Refiners. *Concentration Ratios in Manufacturing Industry*, Report prepared by the Bureau of the Census for the Subcommittee on Antitrust and Monopoly, Committee on the Judiciary, U.S. Senate (Washington, GPO, 1966).

[2] *Economic Analysis of the Copper Industry*, Charles River Associates, 1970, p. 62.

[3] The custom refiners, especially ASARCO, do refine substantial amounts of primary copper.

mills, and a dozen primary smelters which process some scrap.[1]

Data on the relative market shares of primary refined copper, secondary refined copper, and the "secondary" industry (alloy ingot and unrefined scrap) are given in Table 4-2. They show that the concentrated refined copper industry accounts for about 85 percent of total domestic supply, while the unconcentrated "secondary" industry makes up the remaining 15 percent.

The degree of concentration within the domestic copper fabricating industry is unclear. Considerable qualitative analysis indicates that the sector is relatively unconcentrated, and yet Table 4-3 shows surprisingly high concentration ratios. One reason for this discrepancy is that Table 4-1 was compiled using total value added within firms. These data often include value added for noncopper products and thereby result in overestimates of their share of the copper fabricating industry. The extent of these overestimates is unknown, but it is generally believed that the copper fabricating industry is less concentrated than the primary copper industry.

The world copper industry is at least moderately concentrated at the refinery stage. Table 4-4 shows an eight-firm concentration ratio of approximately 63 percent; however, the ownership of much of the capacity included in this table has been changed as a result of nationalization in certain countries. All of the firms listed in Table 4-2 process at least some primary copper

[1] McMahon, *op. cit.*, p. 76.

Table 4-2

MARKET SHARES OF THE PRIMARY AND SECONDARY COPPER PRODUCERS IN THE UNITED STATES, OLD SCRAP AND ESTIMATED PURCHASED NEW SCRAP, 1966

(Thousands of Short Tons)

	Producer				
Product	Primary	Secondary	Scrap Dealers	Total	% of Total
Primary Refined	1,711.0	0	0	1,711.0	65.9
Secondary Refined	437.9	52.8	0	490.7	18.9
Copper Alloy Ingot	0	256.0	0	256.0	9.9
Scrap	0	0	137.8	137.8	5.3
Total	2,148.9	308.8	137.8	2,595.5	100.0
Percent	82.8	11.9	5.3	100.0	

SOURCE: Copper Development Association, New York, *Copper Supply and Consumption, 1947-1966*.

Table 4-3
CONCENTRATION IN THE DOMESTIC COPPER FABRICATING INDUSTRY

SIC Code		4 Firm	8 Firm	20 Firm
3351	Copper Rolling and Drawing			
	1963	45	65	86
	1958	46	66	85
	1954	NA	NA	NA
33511	Copper and Copper-Base Alloy Wire (bare and tinned) for Purposes Other than Electrical Transmission			
	1963	50	71	94
	1958	48	72	94
	1954	NA	NA	NA
33512	Rolled, Drawn and Extruded Copper and Copper-Base Alloy Mill Products			
	1963	47	66	87
	1958	47	67	86
	1954	52	71	89
33572	Copper and Copper-Base Alloy Wire (including strand and cable) Bare and Tinned for Electrical Transmission			
	1963	67	81	95
	1958	65	82	96
	1954	NA	NA	NA
33620	Copper and Copper-Base Alloy Castings			
	1963	17	25	40
	1958	18	25	37
	1954	NA	NA	NA

NA = Not available.

SOURCES: *Concentration Ratios in Manufacturing Industry, 1958*, and *Concentration Ratios in Manufacturing Indsutry, 1963*. Reports prepared by the Bureau of the Census for the Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, U.S. Senate, 87th Congress, 2nd Session (Washington, Government Printing Office, 1962), pp. 140-143, 165; and 89th Congress, 2nd Session, 1963 (Washington, Government Printing Office, 1966).

Table 4-4
PRIMARY REFINED COPPER PRODUCERS, 1968

Rank	Company	Refinery Capacity (000 s.t.)	Cumulative Refinery Capacity	Cumulative Percent of World Total
1	The Anaconda Company[1]	876	876	11.5
2	Generale Congolaise des Minerais[2] (Union Minière du Haut Katanga)	827	1,703	22.4
3	Kennecott Copper Corporation[3]	745	2,448	32.2
4	Phelps Dodge Corporation	626	3,068	40.4
5	American Smelting and Refining Co.*	612	3,680	48.4
6	Anglo-American Corporation of South Africa, Ltd.	379	4,059	53.4
7	Roan Selection Trust, Ltd.	366	4,425	58.3
8	Noranda Mines, Ltd.	342	4,767	62.8
9	American Metal Climax, Inc.*	260	5,027	66.2
10	Norddeutsche Affinerie*	220	5,247	69.1
11	British Copper Refineries, Ltd.*	190	5,437	71.6
12	Mitsubishi Metal Mining Co., Ltd.*[4]	175	5,612	73.9
13.	International Nickel Company of Canada	168	5,780	76.1
14	Nippon Mining Company, Ltd.	159	5,939	78.2
15	Electrolytic Refining and Smelting Co.[5]	134	6,073	80.0
16	Sumitomo Metal Refining Co., Ltd.*	111	6,184	81.4
17	Mount Isa Mines, Ltd.	110	6,294	82.9
18	Empresa Nacional del Mineria*	93	6,387	84.1
19	Copper Range Company[6]	90	6,477	85.3
20	Cerro Corporation[7]	89	6,566	86.5

(Table continued on following page.)

Table 4-4 (Continued)
PRIMARY REFINED COPPER PRODUCERS, 1968

Rank	Company	Refinery Capacity (000 s.t.)	Cumulative Refinery Capacity	Cumulative Percent of World Total
21	Soc. Espanola de Construcciones Electro-Mecanicas*[8]	86	6,652	87.6
22	Mitsui Mining and Smelting Co., Ltd.*	83	6,735	88.7
23	Rudarsko Topionicarski Bazen, Bor	77	6,812	89.7
24	Inspiration Consolidated Copper Co.	70	6,882	90.6
25	Enfield Copper Refining Co., Ltd.*	67	6,949	91.5
26	Huttenwerke Kayser Aktiengesellschaft*	61	7,010	92.3
27	Bolidens Aktiebolag*	55	7,065	93.0
28	Outokumpu Oy	53	7,118	93.7
29	Palabora Mining Company, Ltd.	45	7,163	94.3
30	Indian Copper Corporation, Ltd.	42	7,205	94.9
31	Furukawa Electric Company, Ltd.*	40	7,245	95.4
32	La Métallo-Chimique, S.A.*	40	7,285	95.9
33	Dowa Mining Company, Ltd.*	40	7,325	96.4
34	Messina (Transvaal) Development Co., Ltd.[9]	31	7,356	96.9
35	Calumet and Hecla, Inc.	30	7,386	97.3
36	Empresa Minera de Mantos Blancos, S.A.	29	7,444	98.0
37	Elkington Copper Refining Co., Ltd.*	29	7,444	98.0
38	Falconbridge Nickel Mines, Ltd.	28	7,472	98.4
39	Soc. Industrial Asturiana "Santa Barbara"*	22	7,494	98.7
40	Electrolitis del Cobre, S.A.*	22	7,516	99.0
41	Montanwerke Brixlegg, G.m.b.H.*	20	7,536	99.2
42	Metallhuttenwerke Lubeck, G.m.b.H.*	18	7,554	99.5
43	Toho Zinc Co., Ltd.*	16	7,570	99.7

(Table continued on following page)

Table 4-4 (Continued)
PRIMARY REFINED COPPER PRODUCERS, 1968

Rank	Company	Refinery Capacity (000 s.t.)	Cumulative Refinery Capacity	Cumulative Percent of World Total
44	Quincy Mining Company	12	7,582	99.8
45	Rabak Elektrolitik Bakir Fabrikasi*	9	7,591	99.9
46	Korea Mining and Smelting Corp.*	3	7,594	100.0

*Custom refiner and/or significant secondary producer.

†Copper is produced as a by-product.

[1]Includes: Andes Copper Mining Co. (99.446%) - 72,000 ton/year capacity; Chile Exploration Co. (99.756%) - 405,000 ton/year capacity; Cobre de Mexico, S.A. (25%) - 59,400 ton/year capacity and International Smelting and Refining Company, (100%) which has refinery capacity in the U.S. Skinner States that Cobre de Mexico is operated by Anaconda.

[2]Includes: S.A. Métallurgie Hoboken (Belgium) - 496,000 ton/year capacity; Cie. Générale d'Electrolyse du Palais (France) - [illegible],000 ton/year capacity.

[3]Includes: Braden Copper Co. (100%) - 180,000 ton/year capacity.

[4]Includes: Onahama Smelting and Refining Co., Ltd. (51%) - 82,000 ton/year capacity. Dowa Mining and Furukawa Electric Company also own part of Onahama.

[5]60 percent of the stock of Electrolytic Refining and Smelting is held by Broken Hill South, which is, in turn, closely related to Broken Hill Associated Smelters Pty., Ltd.

[6]Copper Range's copper refining operations are carried on by the White Pine Copper Company, a wholly-owned subsidiary.

[7] Includes: Lewin-Mathes Division of Cerro Corp. (U.S.) - 44,000 ton/year capacity.

[8]Includes: Industrias Reunidas Minero-Metalurgicas S.A. - 20,000 ton/year.

[9]Includes: Messina Rhodesia Smelting and Refining Co., Ltd. - 18,000 ton/year capacity.

SOURCE: American Bureau of Metal Statistics, Yearbook, 1968.

material, but many -- indicated by an asterik -- are predominantly custom refiners.

Most of the refinery capacity in the major producing areas--the United States, Chile (prior to nationalization), Canada, and Africa--was accounted for the ten largest refiners. In addition to the five major domestic refiners, the "top ten" included three African producers--Union Minière du Haut Katanga (Republic of the Congo); Anglo-American Corporation (Zambia); Roan Selection Trust, Ltd. (Zambia); as well as Noranda Mines, Ltd., a Canadian firm and Norddeutsche Affinerie, a large custom refinery located in West Germany.

Since 1968 both the Chilean and Zambian mines have been nationalized. (Union Minière was nationalized by the Congolese government in 1967.) The Zambian mines are now owned by Roan Consolidated Mines Limited (RCM, formerly RST) and Nchanga Consolidated Copper Mines Limited (NCCM, formerly AAC). The Zambian government owns 51 percent of these two companies, and RST and AAC were compensated for their holdings with both money and stock.[1]

The Chilean government fully nationalized its copper industry early this year and has dropped its contracts with Anaconda to refine Chilean copper. As a result, Codelco, the state copper company, will undoubtedly become a major international copper producer.

The footnotes to Table 4-2 list the subsidiaries whose refinery capacities were included with their

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[1] *Zambia's Copper Mining Industry*, RCM and NCCM, p. 9.

parent companies. There is little or no doubt that effective control of these firms has been exercised by the parent company in each case. There are several other instances where one firm owns a substantial part of another. In these cases, ownership does not clearly imply control, but may nonetheless have some bearing on concentration. In addition, several major copper refiners are very loosely related through overlapping boards of directors, although these relationships probably could not provide an effective mechanism for coordination of pricing and production policies, at least in the short run.[1]

As with the domestic industry there are no readily available concentration data on "secondary" production abroad, but it is reasonable to assume that it is unconcentrated as in the case in the United States.

Vertical Organization

The extent to which an industry is vertically integrated can have an important effect on its behavior for either or both of two reasons. First, economies of vertical integration or an existing high degree of vertical integration can make entry into the industry difficult. Second, in an industry which is not integrated or only partially integrated, price variations at one stage will affect demand and price at other stages.

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[1] *Economic Analysis of the Copper Industry*, Charles River Associates, 1970, pp. 72-73 and Appendix A.

Table 4-5 indicates the pattern of integration in the domestic copper industry through the refinery stage. The integrated primary producers largely supply their smelters and refineries with company-mined ores, and partially integrated primary producers and independent miners account for only a modest part of domestic production. Furthermore, most of the output of these firms is sold to the major custom refiners, ASARCO and Phelps Dodge. ASARCO purchases, on a contract basis, the mine production of the three largest domestic "miners," which in 1966, accounted for nearly 80 percent of the domestic concentrate which was not smelted by the firms that produced it.[1] Phelps Dodge, similarly, contracts for the production of the two partially integrated firms.[2] The implication of these facts is that there is essentially no domestic market for ore, concentrate or blister which influences the primary producers. The full nationalization of Chile's mines clouds this picture, as it deprives Anaconda and Kennecott of much of their blister.

The distinction between the primary producers and the custom refiners is more one of degree than kind. ASARCO mines some copper domestically and holds equity in several foreign mines.[3] Similarly, the other major

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[1]Bagdad Copper Corp., Pima Mining Co., and Duval Sulphur and Potash Co. The disposition of the output of these firms, and of the partially integrated producers is reported in American Bureau of Metal Statistics, *Yearbook*, 1967.

[2]*Metal Statistics Yearbook, 1970*, p. 26.

[3]ASARCO, *Annual Report, 1970*.

Table 4-5

VERTICAL INTEGRATION IN THE DOMESTIC COPPER INDUSTRY, 1970

Type / Stage	Integrated Primary Producers	Custom Refiners	Partially Integrated Primary Producers
Number	5[1]	5	2
Percent U.S. Refinery Capacity	63.0	37.0	0
Percent U.S. Smelter Capacity	66.1	26.9	7.0
Percent U.S. Mine Production	74.4	4.5	9.8

[1] Includes Phelps Dodge.

SOURCE: American Bureau of Metal Statistics, *Yearbook*, 1970.

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custom refiner, American Metal Climax, owns a 20 percent interest in Roan Consolidated Mines Limited, a Zambian producer.[1] On the other hand, Phelps Dodge is generally regarded as an integrated primary producer, although the company apparently purchases or refines for a fee nearly 50 percent of its copper inputs.

A review of the world copper industry reveals that the degree of vertical integration is similar to, but not as complete as, that found in the domestic industry.[2] There are fairly large, partially integrated producers in Canada, Mexico, Chile, the Republic of South Africa, and Southwest Africa. A fringe of mining firms is found in all of the major producing nations, and in addition, Cyprus and the Philippines produce noticeable quantities of copper concentrate. Custom refiners and integrated custom refiners are particularly characteristic of the European market. However, the major foreign producers, like the domestic firms, mine most of the material they refine.[3]

The high degree of integration is not carried through to the fabrication of copper "semis" although an estimated one-third of the refined copper fabricating capacity--presumably mainly wire mills and brass mills--

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[1] AMAX, *Annual Report 1970*, p. 22.

[2] Charles River Associates Incorporated, *Economic Analysis of the Copper Industry*, 1970, pp. 54-56.

[3] *Ibid.*, p. 73.

is captive.[1] Most of this is held by fabricating subsidiaries of the major producers, but significant holdings belong to General Motors, General Electric, and Westinghouse.[2] The conclusion is that the primary copper industry is highly integrated from the mining stage to the refining stage, and is to a lesser extent, integrated forward to the fabrication of copper semis. The foreign producers appear to be less integrated at each stage than the domestic producers.

Physical Distribution

Copper is distributed in several different ways; there are many copper products and an even larger number of copper prices. A complete description of all of these features of the industry is unnecessary, but it is useful to note the more important prices and marketing arrangements.

Copper fabricators sell directly to users and to warehouses, which retail the material. Wire, and to a lesser extent foundry products, will generally be sold directly to the users, but warehouses play a significant role in the distribution of brass mill products.[3] U.S. copper producers--and to a lesser extent, foreign producers--are integrated forward and so are distributors of both refined copper and copper semis.

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[1] *Ibid.*, p. 57.

[2] *Ibid.*

[3] *Copper and Brass Warehouse Association Guide for Marketing Copper, Brass, Bronze*, prepared by the staff of *Metals Week* for the Copper and Brass Warehouse Association, Inc. (Philadelphia, the Association, 1968) p. C-61.

The major producers are the most important distributors of refined copper. Approximately 80 to 85 percent of the primary refined copper produced each year is transferred by producers to their own fabricating plants or sold to independent fabricators.[1] Most of the major suppliers of refined copper have sales subsidiaries which distribute their production and frequently that of smaller producers as well.

Merchants are, after the refiners, the largest distributors of refined copper; and merchants function specifically as distributors. Small mines and smelters are the largest source of merchant copper. Merchants purchase the output of these small producers and then have the material refined (by "custom" refiners) on a toll basis. Merchants also purchase scrap for refining on toll, and some secondary producers sell part of their output to merchants. The exchanges are an additional, but very minor, source of merchant copper.[2]

While many fabricators routinely purchase part of their copper from merchants, merchants are particularly well equipped and willing to handle small and/or irregular demands. Merchants sell copper for both immediate and future delivery. A fabricator, of course, can also purchase future copper on one of the exchanges--the London Metal Exchange (LME) and the Commodity Exchange (COMEX) in New York. The LME's role as a physical market has

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[1]J. Vuillequez, "How Metal Goes to Market," in Robert H. Leseman, ed., *E&MJ Metal and Mineral Markets, Market Guide--Copper, E&MJ Metal and Mineral Markets* (now *Metals Week*) October 25, 1965, p. 23.

[2]J. L. Chinder, "The Merchants' Role", *op. cit., Market Guide*, pp. 26-27.

increased over the years, but even in Europe it plays only a very limited role in distribution, about 7 to 8 percent of European consumption and less than 1 percent of world consumption.[1]

COMEX is considerably less important in world copper markets than is the LME. Like LME, COMEX is basically a hedge and speculative market, but COMEX is even less of a physical market than LME.

Copper alloy ingot is sold directly to fabricators by "ingot makers"--secondary producers and some foundries and brass mills. Scrap is generally collected by junk yards and sold to dealers, who in turn sell to secondary producers, custom refiners and fabricators. Direct sales of old scrap and copper alloy ingot are approximately 15 percent of total U.S. consumption.[2] Together with the figures presented earlier, this implies that producers distribute approximately 65 to 70 percent of total consumption while merchants distribute the remaining 15 to 20 percent.

Conditions of Entry

The copper industry is generally considered to have high barriers to entry. This is especially true for entry as a large integrated producer. Table 4-6 shows that the capital costs of recent mine-mill-smelter projects generally range from $100 to $230 million. Projects of

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[1] "Metals Week Profile--The London Metal Exchange," *Metals Week*, Vol. 38, No. 35 (August 28, 1967).

[2] See Chapter 3.

Table 4-6

CAPITAL COSTS BY TYPE OF PROJECT

Company	Location	Completion Date	Increment to Capacity (000 s.t.cu/yr)	Capital Cost ($ millions)	Capital Cost per ton ($/ton)
Open Pit Mine					
RST	Zambia	1967	14.3	4.2	293
RST	Zambia	1973	24.6	30.0	1,220
AAC	Zambia	1968	32.0	14.0	437
Cia Minera Exotica	Chile	1970	100.0	47.5	475
Mine and Mill					
New Imperial Mines, Ltd.	Yukon	1967	7.0	7.2	1,030
Bethlehem Copper Corp.	B. C.	1967	8.0	3.7	460
Boliden Grav. A.B.	Sweden	1968	9.0	16.0	1,780
Brenda Mines, Ltd.	B. C.	1969	13.0	50.0	3,840
ASARCO	Arizona	1967	20.0	9.0	450
Pima Mining Co.	Arizona	1967	38.0	37.1	980
Granduc Operating Co.	B. C.	1970	42.5	85.0	2,000
Bor Mining and Smelting Works	Yugoslavia	1970	62.0	144.0	2,320
Phelps Dodge	New Mexico	1970	100.0	55.0	550
Mine, Mill, Smelter					
†*White Pine Copper Co.	Michigan	1967	22.5	37.0	1,640
Etibank Genel Muduruga	Turkey	1971	40.0	40.0	1,000
Palabora Mining Co.	So. Africa	1966	80.0	104.0	1,300

(table continued on next page)

Table 4-6 (Continued)
CAPITAL COSTS BY TYPE OF PROJECT

Company	Location	Completion Date	Increment to Capacity (000s.t. cu/yr.)	Capital Cost ($ millions)	Capital Cost per ton ($/ton)
Mine, Mill, Smelter (continued)					
†Kennecott	Utah	1966	100.0	100.0	1,000
*Braden Copper Co.	Chile	1970	100.0	200.0	2,000
Soc. Minera El Teniente	Chile	1970	100.0	230.0	2,300
Mill-Smelter					
†Chile Exploration Co.	Chile	1970	100.0	75.0	1,333
Smelter					
†ASARCO	various	--	170.0	25.0	147
Refinery					
†Andes Copper Co.	Chile	--	36.0	12.0	333
Palabora Mining Co.[1]	So. Africa		45.0	10.0	450
Empressa Nacional de Mineria	Chile	1966	84.0	25.0	297

†All, or in part, an expansion of an existing facility.

*Underground mine.

[1]Initial capacity.

SOURCE: *Engineering and Mining Journal*, Vol. 169, No. 2 (February, 1968), pp. 83 ff.; Vol. 168, No. 1 (January, 1967), pp. 69 ff.

this magnitude almost certainly can be undertaken only by a large, well-established firm. The data also suggest that the capital costs of developing a large orebody are sufficiently great to be regarded as an entry barrier. This, however, does not imply that capital costs are a barrier to the development of small mines. The capital costs of the smaller integrated projects and mine-mill or mine projects do not seem large enough to be regarded as a barrier to entry.

The only potential "absolute" barrier to entry into the copper industry which appears to have any actual importance is the limited availability of known reserves. Information collected by the U.S. Federal Trade Commission for 1945 indicates that most known reserves were then held by the major producers. In 1945, Anaconda, Kennecott, Phelps Dodge and their subsidiaries held just over 41 percent of the world's copper reserves. The Commission also estimated that ". . . control of not less than 70 percent of the world's known reserves of copper is in the hands of less than ten corporations or financial groups."[1] Since large deposits discovered since then have been developed by the major producers, the pattern of control reflected by this figure is probably still relevant.

The importance of ore reserves as a barrier to entry is in part related to vertical integration. A firm contemplating entry at the smelter or the primary refining stage must find some source of concentrate supplies. It is unreasonable to suppose that an integrated

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[1] *Report of the Federal Trade Commission on the Copper Industry* (Washington, GPO, 1947) p. 38.

producer in possession of an orebody will want to foster the growth of a competitor by selling concentrate. The implication is that entry must be largely a matter of discovering new reserves.

The fact that known reserves are probably held primarily by existing producers is not surprising, and does not prevent any interested firm from searching for a copper deposit. The costs of exploration and development are, then, a basic component of entry costs. The extent to which these constitute an "absolute cost" barrier depends on the distribution of unknown deposits. If the probability of finding an orebody for the expenditure of a reasonable sum is very small, then concentration of ownership of known reserves should be regarded as an absolute cost barrier; but they should not be so regarded as long as prospecting can be carried on with a chance of success. The observed entry by several small Canadian mining firms suggests that reserves are not strictly speaking an absolute cost barrier.

The conclusion suggested is that entry into the copper industry as an integrated producer is probably very difficult because of high capital and absolute cost barriers, although it is certainly possible that any of several large primary metals firms could overcome them. Entry into mining-milling on a relatively small scale, however, is probably not impeded by capital costs or scale economies. Discovering a deposit which can be profitably mined certainly is a barrier,but, at least recently, apparently not an unsurmountable one. This suggests that the most potent entry threat may come from established custom refiners. Custom refiners can

expand only as the "independent mining" sector of the industry grows, and they might therefore encourage the development of small mines. "Although the custom refinery sector of the industry has become relatively less concentrated, in general, there has been little entry into the refining stage of the industry during the postwar period."[1]

The significance of entry by smaller mines is open to doubt. The size of individual mines is usually an extremely small part of total supply, and the life of such mines is probably short. What is important are changes in the size of the independent mining sector, which apparently has not increased over time. Entry by small mines or even large ones cannot be ruled out *a priori* but it probably has not been a significant factor during the period studied.

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[1]Charles River Associates Incorporated, *Economic Analysis of the Copper Industry*, 1970, pp. 100-101.

Chapter 5

COPPER PRICES

Refined Copper-Price Quotations

There is no single price which can be clearly labeled "the" prevailing world price of refined copper. There are several "producer prices," two important average prices, the merchant or "outside price" as well as the LME (London Metal Exchange) and the COMEX (Commodity Exchange) prices.

The most important refined copper prices in the United States are the "domestic producer price" and the "custom smelter price." Anaconda, Kennecott, Phelps Dodge and the smaller U.S. producers generally make domestic sales at a common "producer price," quoted in cents per pound for electrolytic wire bars delivered in the United States. The "custom smelter price" published in *Metals Week* is ASARCO's price. AMAX, the other major domestic custom refiner, apparently bases its sales on

this price when it is above the producers' price.[1]

Approximately 75 percent of total domestic refined copper consumption, including secondary refined copper from old and new scrap, is generally sold at either the domestic producer price or the custom smelter price. The remainder is sold at the merchant price, one of the average prices, or, for imports, a price which may vary with the source.

The LME price is far more important than the role of the exchange as either a physical or a hedge market would indicate. The LME spot price, three month future price, and averages of LME prices are commonly used for sales made in Europe and in international trade. In particular, for much of the postwar period, RST and AAC sold at the LME price -- at first the spot price on the date of delivery and more recently at the three month futures price. Between 1955 and 1957 RST sold at announced producer prices, and in the period 1964-1966 RST and AAC sold at a common producer price.[2] Union Minière (UMHK), the other major African producer, sold at an announced price. The Canadian producers have generally made sales in the United States at the domestic producer price, and sales outside the United States at the LME price. The price of Chilean copper has been

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[1]AMAX is the only domestic producer of oxygen-free, high conductivity copper (OFHC). This product sells at a premium over electrolytic copper. *Materials Survey, op. cit.*, p. 263.

[2]"Marketing of Primary and Secondary Copper," *Mining Magazine*, Vol. 117, No. 4 (October 1967) p. 279.

fixed by the Chilean government since 1952.[1] Until the recent nationalization of the Chilean copper industry, Chilean copper had generally, but not always, been sold in the United States at the domestic producers' price and outside the United States at the LME price.[2]

Whereas Chilean copper was formerly sold mainly by Anaconda and Kennecott, the new Chilean state mining corporation Codelco has appointed numerous subagencies to sell its copper throughout the world. It is commonly believed that Chile will now sell her copper in line with the LME price.[3]

The most important average price is the *Metals Week* "export refinery price," which is a weighted average of the prices charged on all sales made outside the U.S. by Anaconda, Kennecott, Phelps Dodge, ASARCO, AMAX, RST, UMHK, INCO, Noranda and several smaller producers. AAC is the only major producer whose sales are not included.[4] The Japanese producers (who sold at their own producers' price through the late 1950's[5]), switched in 1967 from the LME price to the *Metals Week* export price,[6] and now

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[1] *Minerals Yearbook, 1952*, Vol. I, p. 345.

[2] "Marketing of Primary and Secondary Copper," *op. cit.*, p. 275.

[3] *Metal Bulletin*, March 5, 1971, p. 14.

[4] "Market Guide," *op. cit.*, p. 41. *Metals Week* also publishes a "domestic refinery" price which is the weighted average price of sales made in the U.S., and is occasionally used in pricing copper.

[5] R. L. Prain, "Copper Pricing Systems"; address to Organization for European Economic Co-operation, Paris, June 25, 1958, reprinted in, *Selected Papers of Sir Ronald Lindsay Prain*, Vol. II (London, B.T. Batsford), p. 15.

[6] *Metal Bulletin* (London), December 1, 1967.

have reverted back to an "official sales price based upon the LME settlement covering the preceding half-month."[1] It was estimated that in 1958 approximately 14 percent of world refined copper consumption was sold at the *Metals Week* price.[2] The *Metal Bulletin* (London) publishes a weighted average price which is very similar to the *Metals Week* price, but this is apparently not used extensively.[3] *Metals Week* also publishes a "domestic refinery price." This is a weighted average of the prices received from all sales (by reporting firms) in the United States of both domestic and foreign copper.[4]

Some nations have their own, highly individual price systems. In France, for example, an apparently semi-official central organization, Groupement d'Importation et de Ripartition des Métaux, purchases the country's "minimum requirements" of copper. Each consumer is allocated a quota, but, within the constraints of exchange control, consumers may purchase additional copper from whomever they please. The Australian government fixes the domestic price, and to some extent subsidizes production.[5]

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[1] *Ibid*, July 9, 1971, p. 12.

[2] Herfindahl, D. C., *Copper Costs and Prices: 1870-1957* (Baltimore: John Hopkins University Press, for Resources for the Future, 1959), p. 186.

[3] "Market Guide," October 25, 1965, p. 41.

[4] Before 1959 only domestic deliveries by U.S. producers were included in the domestic refinery price; deliveries by foreign producers in the U.S. and foreign deliveries by U.S. firms were included in the export refinery price. See *CABWA Market Guide*, p. C-59.

[5] Prain, *op. cit.*, p. 20.

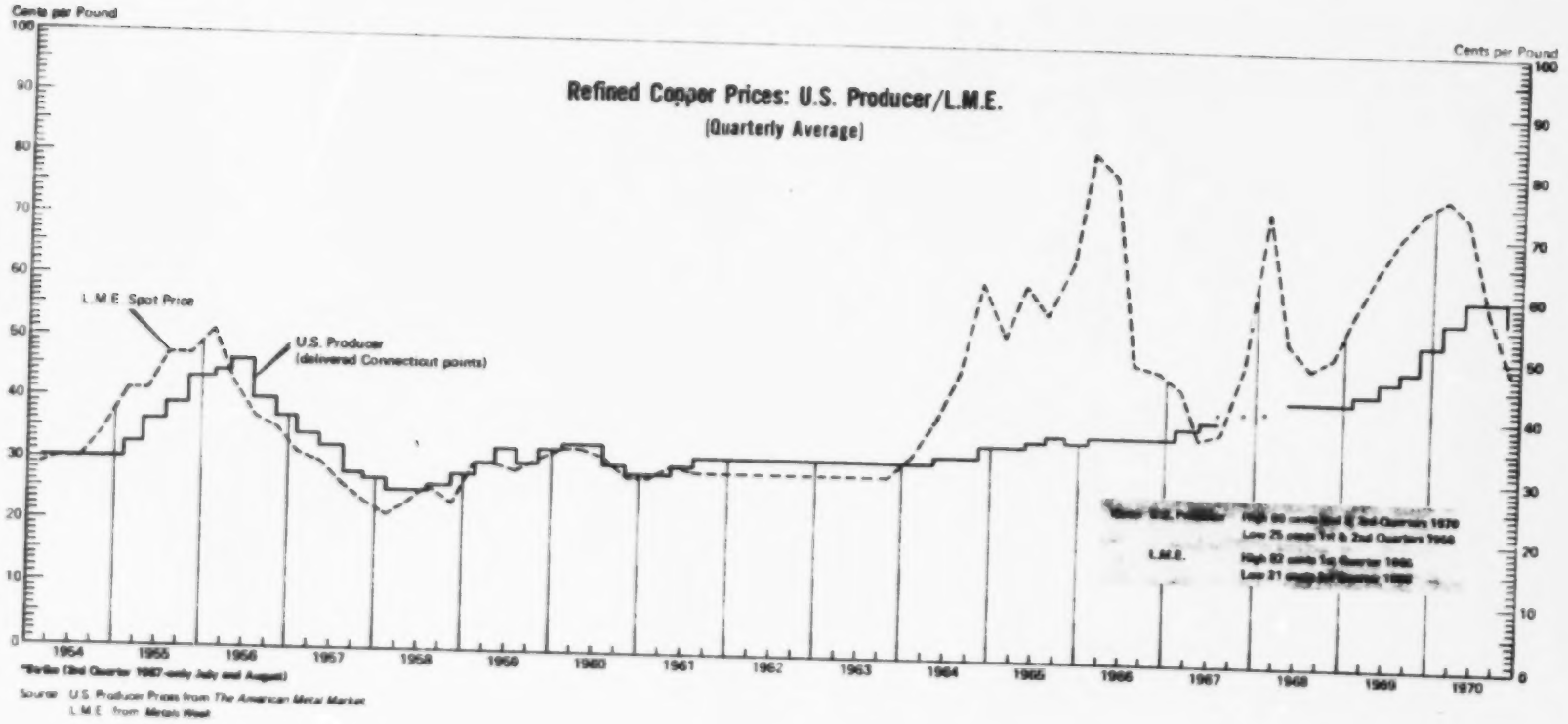
Price History

Figure 5-1 compares the domestic producers' price of copper with the LME price for the period 1954-1970. The LME price, which represents the marginal transaction price in the market, increased to a local peak of about $0.52 in early 1951, fell steadily to a low of about $0.21 in 1958, and then increased to levels of about $0.30 during the years 1959-1963. The price then rose sharply to a peak of about $0.82 in 1961 and has fluctuated between $0.35 and $0.77 per pound since then. The current price is about $0.48 per pound. The overall trends in the domestic producers' price have been similar. However, the domestic producers' price tends to be quite stable and has not increased rapidly during periods of particularly strong demand (such as the years 1964-1966 and 1968-1970). In general, copper prices during the past two decades have not increased substantially relative to other industrial materials, although they have increased relative to the market prices of aluminum -- the principal substitute for copper.

Custom refiners process a great deal of scrap, and scrap prices fluctuate considerably in the short run. (The same is true of alloy ingot prices.) In general, the custom refinery price, scrap prices and the LME price move together sufficiently closely so that it is both difficult and fairly unimportant to distinguish among them.

Primary and secondary refined copper can safely be regarded as perfect substitutes and the two largest domestic custom refiners, ASARCO and AMAX, together hold over 30 percent of domestic refinery capacity. It is conceivable,

Figure 5-1



Reprinted from Copper, Quarterly Industry Report, U.S. Department of Commerce, April 1971.

therefore, that custom refiners could satisfy much of the domestic demand for copper for short periods of time. It would seem from this that the custom refiners' price should have a definite impact on the domestic producers' price. It appears, in fact, that the producers' price often follows the custom refiners' price when the latter is declining, but that increases in the custom refiners' price alone are not usually sufficient inducement for the domestic producers to raise their price.[1]

It is quite clear that the U.S. domestic producers believe it to be in their interests to keep copper prices low and stable. Their principal concern has apparently been that high prices of copper will in the long run induce substitution of aluminum and other materials for copper and that their lost markets will not be regained by a future dip in copper prices.

During periods in which producer capacity is insufficient to meet demand at the producers' price, the producers have chosen to ration copper instead of to raise the price to the short-run market-clearing level. Of course, rationing at low prices may be just as strong a stimulus for long-run substitution as unlimited sales at high prices.

A complete explanation of the two-tier price system, with a low U.S. producers' price and a high LME price, is quite complex and beyond the scope of this report. Briefly, however:

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[1]Charles River Associates, Incorporated, *Economic Analysis of the Copper Industry*, May 1970, p. 145-147.

> The U.S. producers set the U.S. producer price to reflect what they believe is a sustainable (and profitable) long-run level of copper prices, taking into account their own resulting supply decisions. They then take that price as given for the time being, believing it in their interest to have a relatively stable price, and decide on the amount of copper they will supply at that price. Other countries selling at the U.S. producer price do the same. . . The difference between U.S. total copper consumption and U.S. available supplies (primary, secondary, and imports) is the decrease (or increase) in U.S. [producers'] inventories. If inventories tend to increase for some period of time and the LME price is below the U.S. producers' price, then producers gradually conclude that they set too high a price and that the proper *long-run* price is below the U.S. producer price. On the other hand, if inventories are being depleted over some period of time and the LME price is well above the U.S. producer price, then the producers gradually conclude that the proper *long-run* price is above the U.S. producer price. They then readjust the U.S. producer price in the indicated direction and the process begins again.[1]

The LME price is determined in an open auction marketplace, and in this sense is clearly a free market price. However, the foreign copper market is fairly concentrated, although less so than in the United States, and there is evidence that the foreign producers recognize their mutual interdependence in the market. As a result, in some periods of weak demand the foreign producers have supported the LME price by mutual output reductions. There is also evidence that the foreign producers may share

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[1]Franklin M. Fisher and Paul M. Cootner, "An Econometric Model of the World Copper Industry", Massachusetts Institute of Technology, Department of Economics Working Paper, April 1971, pp. 3-4.

the U.S. producers' fear of overly high prices, and at times have acted to restrain prices from increasing too rapidly.

In particular, there have been two "producers' price experiments" in which the foreign producers have openly attempted to coordinate their price and output policies.

The first producers' price experiment began in May 1955 when RST announced that it would sell at a price of $0.35/lb. delivered in the United Kingdom. The price was to be held for 30 days and was then subject to change on 24-hours notice. The LME price was $0.45/lb. at the time. For the next two years the RST quoted a price, domestic producers quoted another, and both differed from other major producers which sold at the LME price or a price closely related to it.[1] In October 1957, RST resumed its earlier policy of selling at the LME spot price. The experiment had failed to control the rapid increase in the LME price which continued from mid-1954 until early 1956, and had apparently done nothing to retard the subsequent rapid decrease which continued until early in 1958. RST attributed its failure to the lack of cooperation from other producers. Conditions in the copper market in the early 1960's led to an attempt by the two major African producers, RST and AAC, to support a high price from October 1961 to mid-1963. RST reduced production by 15 percent and AAC reduced sales and accumulated stocks.[1] At the end of this period demand increased sharply, RST and AAC were unable to meet the increase at the maintained price and the price increased.[2] At this point RST and AAC

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[1]CRA, *Economic Analysis of the Copper Industry*, p. 163-166.

began an attempt to limit the price increase in what is known as the "second producers' price experiment":

> Fearing substitution away from copper, if prices were allowed to rise, the producers . . . announced that they would continue to supply their customers at a price of £236 a ton. . .[3]

a price of only £2 above the price which they had supported for the previous two and one-half years. All the other major producers including U.S. domestic producers, closely followed this policy. During the next two years producers' prices did increase on five occasions in response to pressure from the Chilean government, which is said to have accepted the policy of price stabilization but to have favored stability at a higher level than the producers.[4] The experiment ended in 1966 when Chile forced Anaconda and Kennecott to increase their price from $0.42 to $0.62. At this point the African producers abandoned fixed price selling in favor of the LME three-months future price. U.S. producers, however, continued to sell at a producers' price.

The copper market has been in severe disequilibrium during much of the past four years. The LME and scrap prices were substantially above the U.S. producers' price between late 1967 and mid-1970, indicating that the domestic producers could not supply all the copper demanded at

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[1] "Marketing of Primary and Secondary Copper," *Mining Magazine*, Vol. 117, No. 4 (October, 1967), p. 275.

[2] Robert Perlman, "The Great Copper Killing," *Management Today*, September, 1966, p. 71.

[3] *Ibid*, p. 71.

[4] *Engineering and Mining Journal*, Vol. 165, No. 4 (April, 1964), p. 23.

their list price and were being forced to ration their output. It is not known whether the principal foreign producers were also rationing at lower prices or were selling all their output at the LME price. The domestic producers' price was increased in a number of small increments between early 1969 and mid-1970, from $0.43 to $0.60. However, the producers' and "free market" price was not brought into equilibrium until mid-1970 when free market prices dropped rapidly to the level of the U.S. producers' price. This decline can probably be attributed to the U.S. recession -- demand for copper fell far enough that the domestic producers no longer had to ration their copper. At the present time the LME price is $0.48 per pound and the domestic producers' price is $0.53 per pound.

We can conclude that the copper market is highly structured with a number of participants -- the integrated domestic producers, the major domestic custom refiners, a small number of foreign producers, and producing countries -- each able to exert a noticeable influence on prices. The U.S. government has also been an effective participant in the market (see Chapter 6). The market is therefore not fully competitive in the economic sense and the allocation of copper to consumers is at times achieved by producers consciously rationing their output among their customers.

The CRA Model of the Copper Market[1]

To evaluate the effects of various anti-pollution measures we must first have an understanding of the copper market. A simple model of the copper market should enable us to show how increased costs in producing copper due to anti-pollution measures will affect the supply of copper, the price of copper, and hence the demand for copper, and the U.S. position in the international copper market.

For ease of exposition we will assume market equilibrium in both the foreign and domestic markets. This means that at the "correct" prices supply equals demand and because of this equality, there is neither rationing among users of copper nor unwanted increases in inventory. These assumptions allow us to concentrate on a simple seven-equation model: two demand equations, one price equation, two supply equations, and two market-clearing identitites.

Copper is almost exclusively an intermediate good. That is, the demand for copper is derived from the demand for goods using copper. The demand for copper (C)[2] is therefore related to the level of production of goods using copper (X), the price paid for copper (P), and the price paid for metals competing with copper in the production process (P_A). We will designate this functional relationship as:

$$C = f_1 (P, X, P_A). \qquad (1)$$

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[1]We developed a complex model of the world market in *An Econometric Model of the Copper Industry*, September 1971. A simplified version of the model is presented here.

[2]The letters in parenthesis following the description of a variable will be used to represent that variable in the equation.

Distinguishing between copper refined domestically and copper refined abroad, we have two sources of supply. The supply of domestically refined copper (Q_D) will depend on the price of copper; the cost of mining, smelting, and refining copper (E); and the domestic refinery capacity ($\bar{Q}$). This relationship will be written as:

$$Q_D = f_2 (P, E, \bar{Q}). \quad (2)$$

Similarly, there will exist a supply function of copper from the rest of the world (Q_{ES}). Copper can almost always be bought and sold at the London Metal Exchange (P_{LME}). We will, therefore, use that price to represent the price of copper in the rest of the world. To simplify matters we will assume the supply of copper from the rest of the world depends only on the London Metal Exchange price for copper. We will write this as:

$$Q_{ES} = f_3 (P_{LME}). \quad (3)$$

Also in the interest of simplicity we will assume the demand for copper by the rest of the world (C_E) depends only on the LME price. This relationship is simply:

$$C_E = f_4 (P_{LME}). \quad (4)$$

The domestic price of refined copper is a producer price and is not determined in a free market. It is very difficult to describe exactly how the producer price is established, but it seems reasonable that the pricing decisions should be influenced by the prices of copper on other markets, the ratio of output to capacity, and the cost of producing refined copper. This relationship would then be described by the equation:

$$P = f_5 \left(P_{LME}, \frac{Q_D}{\bar{Q}}, E\right). \quad (5)$$

Finally, we have two market clearing equations, one for the United States and one for the rest of the world:

$$C = Q_D + M \quad (6)$$

and

$$C_E = Q_E - M. \quad (7)$$

Net imports of copper (M) is therefore a residual determined in the solution of the model. For example, if the U.S. price of copper was high relative to the foreign price of copper there would be excess supply of copper in the United States, excess demand in the rest of the world and hence the United States would export copper (M would be negative). The solution of the model also determines the U.S. producers' price of copper (P) and the LME price of copper (P_{LME}).

Evidence on Price and "Income" Elasticities of Demand

Econometric estimates of the effects on domestic copper consumtion of changes in the price of copper and the level of economic activity as measured by a number of indexes of activity, have been developed by two authors. These estimates, expressed as elasticities, are presented in Table 5-1 along with new estimates prepared in the course of the present study. Elasticity measures the percentage change in copper consumption resulting from a 1 percent change in one of the variables given in the table, all other things remaining unchanged. Both short-run and long-run elasticities are given. The short-run estimates measure the effect on copper consumption that would occur in one year; the long-run estimates measure the full effect on consumption after all adjustments have had time to take place.

Four sets of estimates are shown in Table 5-1. They all agree that in the short run the demand sensitivity to copper price is low. A 10 percent change in copper price would reduce consumption in the same year by less than 3 percent. Except in one set of estimates the important influence on changes in short-run consumption is change in the general level of economic activity as represented by an index such as the Index of Durable Manufactures.

In the long run all the CRA estimates and one set of the Fisher estimates are in agreement that the level for economic activity is of greatest importance than copper prices in determining consumption. In the latest estimates a change of 10 percent in copper or in the Index of Durable Manufactures is accompanied by a change of more than 10 percent in copper consumption. (Note that the variables may change together in such a way as to compensate for each other or to reinforce each other.)

Our new estimates are probably to be preferred on the grounds that the demand function from which they are derived appears to reflect recent changes in consumption more accurately than the earlier demand functions. It is distinguishable from the earlier estimates in that only changes in the level of economic activity have very much influence on consumption in the short run and that consumption is sensitive to price changes, but only in the long run. If "real" prices, "deflated" or "constant dollar" prices, remained unchanged the net estimates suggest that copper consumption would grow at a rate of about 20 percent faster than the Index of Durable Manufactures.

Table 5-1
ELASTICITY ESTIMATES FOR U.S. COPPER DEMAND

	Short-Run	Long-Run
Charles River Associates Estimates[1]		
Copper Price	-.335	-.796
Index of Durable Manufactures	.442	1.050
Fisher Estimates[2]		
Copper Price	-.213	-.900
Index of Construction Materials	.332	1.40
Copper Price	-.173	-.817
Index of Industrial Production	.153	.732
New CRA Estimates		
Copper Price	-.035	-1.117
Index of Durable Manufactures	.509	1.212

[1] *Economic Analysis of the Copper Industry*, CRA (1970).

[2] *An Econometric Model of the World Copper Industry*, F. M. Fisher, et. al., April 1971.

Chapter 6

GOVERNMENT POLICIES

The U.S. government affects the copper industry by its general economic policy actions and by participating directly in the market. It also subsidizes exploration and supports the two-tier copper price system with export limitations.

Copper Stockpile Program

As of September 30, 1971 the General Services Administration had 251,615 short tons of copper in government stockpiles, which represents 14 percent of total 1970 domestic consumption. This is considerably less than the desired objective for the stockpile which is 775,000 tons. At times, in the past, stocks have been considerably above the objective. Large quantities have been released in the past decade, at first to bring stocks more closely in line with the objective and more recently to assist in stabilizing the market in periods of excess demand.

On December 31, 1964 inventories of copper in government stockpiles totaled 1,095,483 tons. From 1965 through 1968 the government released 760,000 tons from its stockpile and 62,000 tons from Defense Product Act Inventories. During 1969 only about 8,000 tons of copper were released.

Trade Policies

The domestic tariff on primary copper products has generally been low, and for some time refined copper entered the United States duty free; but in 1958 the U.S. tariff on ore concentrate, matte, blister, refined copper, scrap and many semifabricated products became $0.017 per pound (copper content). In accordance with the Kennedy Round tariff reductions this tariff was reduced by stages to $0.01 per pound in January, 1971. Since February, 1966, however; tariffs have been suspended on copper-bearing ores and materials, blister copper, anode copper, all other unwrought copper (except that containing nickel and silver), as well as copper waste and scrap; the most recent suspension expires in June, 1972.[1] Since these materials are presently entering the United States duty-free, they are apparently not subject to the current 10 percent import surcharge.

The tariffs on various forms of refined copper and fabricated copper products are still in effect, and vary

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[1] *Copper Quarterly Industry Report*, January 1969.

according to type. Since the 1930 tariffs on these products are usually less than the present tariff plus the 10 percent surcharge, the former will be the effective tariff as long as the 10 percent surcharge continues.[1]

The U.S. government has also effected severe quota limitations on the export of refined copper and scrap. In 1969 exports of refined copper from domestic primary sources and scrap were limited to 50,000 and 60,000 short tons of contained copper, respectively.[2] Export controls may be part of the explanation of why prices in Europe can sometimes remain at levels far higher than domestic copper prices. As the LME price has declined and even fallen below the domestic producers' price, these restrictions have been modified, and in September, 1970 the United States lifted its copper short-supply Export-Control Restrictions.[3] The restrictions were reinstated, however, in 1971.

Foreign tariffs on primary copper products are also generally low. In 1964, the Scandinavian countries, Austria, Switzerland, and the EEC admitted unwrought copper duty-free. The British tariff ranged from zero to 10 percent *ad valorem*.[4]

Trade in fabricated products is to some extent limited by tariffs. The domestic tariff on fabricated products is generally modest, but some European tariffs

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[1] *Metals Week*, August 23, 1971, p. 2.

[2] *Minerals Yearbook 1969*, p. 451.

[3] *Copper Quarterly Industry Report*, U.S. Department of Commerce, January 1971, p. 10.

[4] Political and Economic Planning Committee, *Atlantic Tariffs and Trade*, (London; Allen and Unwin, 1962).

are substantial. In 1962, for example, the EEC duties, were in the range of 13-15 percent *ad valorem*, and the British tariff on some copper semis was 20 percent.[1]

Price Controls

The U.S. government has directly intervened on several occasions to influence or control copper prices. The best known occasion was in November 1965 after Anaconda and Kennecott had agreed to Chile's demand that they raise their prices in the U.S. from $0.36 to $0.39 per pound. The government persuaded the producers to rescind the increase so as to conform to Guidepost policy. Three months later, in officially separate actions, Chile agreed to sell 100,000 tons in the United States at the producers' price of $0.36 and the U.S. government, through the Alliance for Progress, agreed to lend Chile $20 million for forty years for use in copper development. In addition, Anaconda, the importing company, was to pay a $3.5 million export surtax to Chile.[2]

Another instance occurred in March 1966, when government agencies were directed to use acceptable substitutes for copper whenever possible. This order was made in light of the excess demand for copper, and at the same time the government made $100,000,000 available for the Copper

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[1]Political and Economic Planning Committee, *op. cit.*, p. 233.

[2]*Copper Quarterly Industry Report*, U.S. Department of Commerce, January 1971, p. 10.

Production Expansion Program. The Copper Substitution Order was subsequently rescinded in August 1968.

The recent price freeze has not affected refined copper prices because a provision in the Economic Stabilization Act of 1970 states that prices cannot be frozen at levels less than those prevailing on May 25, 1970. On that date U.S. producer copper sold at $0.60 per pound and the COMEX price was quoted at $0.658. As a result, copper producers presently have a price ceiling considerably above the prices now prevailing.

Chapter 7
THE COPPER INDUSTRY IN THE UNITED STATES

This chapter describes the distribution among the states of the domestic copper industry in terms of output, production capacities, and employment in mining and in smelting and refining. It also discusses the relationship between the copper industry and the local economy in Arizona, the state in which the industry is most heavily concentrated, and in locations where it appears the industry is especially sensitive to adverse impacts of pollution abatement legislation. Finally, the financial performance of the major copper producers is discussed from the standpoint of their ability to finance capital expenditures for pollution control.

Geographical Distribution of the Domestic Industry

Mining

The principal copper producing states are Arizona, Utah, New Mexico, Nevada, and Michigan. Annual production

figures of these states are listed in Table 7-1. Arizona is the leading producer by a wide margin, but Utah's production is substantial. The percentages of 1970 domestic production for the principal states are as follows:

PERCENTAGE DOMESTIC PRODUCTION IN 1970

State	Percent
Arizona	53.3
Utah	17.3
New Mexico	9.7
Montana	7.2
Nevada	5.9
Michigan	4.1
	97.5

The twenty-five leading copper-producing mines in the United States for 1969 are listed below in order of output:

Rank	Mine	County and State	Operator
1	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp.
2	Morenci	Greenice, Ariz.	Phelps Dodge Corp.
3	San Manuel	Pinal, Ariz.	Magma Copper Co.
4	Ray Pit	" "	Kennecott Copper Corp.
5	Chino	Grant, N. Mex.	" " "
6	White Pine	Ontonagon, Mich.	White Pine Copper Co.
7	Berkeley Pit	Silver Bow, Mont.	The Anaconda Co.
8	New Cornelia	Pima. Ariz.	Phelps Dodge Corp.
9	Pima	" "	Pima Mining Co.
10	Copper Queen-Lavender Pit	Cochise, Ariz.	Phelps Dodge Corp.

Table continued on following page.

Rank	Mine	County and State	Operator
11	Inspiration	Gila, Ariz.	Inspiration Consolidated Copper Co.
12	Yerington	Lyon, Nev.	The Anaconda Co.
13	Mission	Pima, Ariz.	American Smelting and Refining Co.
14	Veteran-Tripp Pit	White Pine, Nev.	Kennecott Copper Corp.
15	Butte Hill Copper Mines	Silver Bow, Mont.	The Anaconda Co.
16	Mineral Park	Mohave, Ariz.	Duval Corp.
17	Silver Bell	Pima, Ariz.	American Smelting and Refining Co.
18	Copper Cities	Gila, Ariz.	Tennessee Corp.
19	Esperanza	Pima, Ariz.	Duval Corp.
20	Magma	Pinal, Ariz.	Magma Copper Co.
21	Bagdad	Yavapai, Ariz.	Bagdad Copper Corp.
22	Tyrone	Grant, N. Mex.	Phelps Dodge Corp.
23	Copperhill	Polk, Tenn.	Tennessee Copper Co.
24	Copper Canyon	Lander, Nev.	Duval Corp.
25	Twin Buttes	Pima, Ariz.	The Anaconda Co.

SOURCE: *Minerals Yearbook, 1969*, p. 464.

In 1970 the average total number of employees in U.S. copper mining was 37,000 of which 29,500 were production workers.[1] Employment levels for the mines listed above are shown in Table 7-2. The total employment for the twenty-five leading mines is 30,700 (but note that this figure and the total U.S. figures come from different sources and may not be consistent).

[1] *The Copper Industry*, Arizona Department of Mineral Resources, Phoenix, September 1971, p. 22.

Table 7-1

MINE PRODUCTION OF RECOVERABLE COPPER

COPPER PRODUCED FROM DOMESTIC ORES FOR SEVERAL STATES

(Thousands of Short Tons)

State	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Arizona	587.1	644.2	661.0	691.0	703.4	739.6	501.7	628.0	801.4	910.0
Michigan	70.2	74.1	75.3	69.0	71.7	73.4	58.5	74.8	75.2	69.5
Montana	104.0	94.0	79.8	103.8	115.5	128.1	65.5	69.5	103.3	123.0
Nevada	78.0	82.6	81.7	67.3	71.3	78.7	50.8	77.2	104.9	100.0
New Mexico	79.6	82.7	83.0	86.1	98.7	108.6	75.0	90.8	120.0	165.3
Utah	213.5	218.0	203.1	119.6	259.1	265.4	168.6	228.2	296.7	295.0

SOURCE: *1970 ABMS Yearbook*, p. 34

Table 7-2

1970 EMPLOYMENT LEVELS IN THE TWENTY-FIVE LEADING COPPER-PRODUCING MINES

(Thousands of Employees)

Rank	Mine	Employment
1	Utah Copper	7.4
2	Morenci	2.1
3	San Manuel	2.2
4	Ray Pit	1.5
5	Chino	1.5
6	White Pine	2.7
7	Berkeley Pit	NA
8	New Cornelia	1.2
9	Pima	0.5
10	Copper Queen-Lavender Pit	1.8
11	Inspiration	NA
12	Yerington	0.5
13	Mission	0.6
14	Veteran-Tripp Pit	1.3
15	Butte Hill Copper Mines	3.0
16	Mineral Park	0.4
17	Silver Bell	0.4
18	Copper Cities	NA
19	Esperanza	0.5
20	Magma	1.1
21	Ragdad	0.5
22	Tyrone	0.4
23	Copperhill	NA
24	Copper Canyon	0.3
25	Twin Buttes	1.0

SOURCE: "International Directory of Mining and Mineral Processing Operators," *Engineering and Mining Journal*, 1970.

Smelting

The domestic copper smelters and their respective estimated capacities (in short tons) at the end of 1970 are listed below.

Company	Situation	Annual Capacity, Tons of Material (input)
ASARCO	El Paso, Texas	576,000
ASARCO	Hayden, Ariz.	960,000
ASARCO	Tacoma, Wash.	600,000
Anaconda Co.	Anaconda, Mont.	1,000,000
Cities Service Co. Copperhill Operations	Copperhill, Tenn.	90,000
Inspiration Consolidated Copper Co.	Miami, Ariz.	450,000
Magma Copper Company:		
Superior Division	Superior, Ariz.	150,000
San Manuel Division	San Manuel, Ariz.	403,000
Kennecott Copper Corp.:		
Nevada Mines Division	McGill, Nev.	400,000
Chino Mines Division	Hurley, N.M.[1]	400,000
Ray Mines Division	Hayden, Ariz.	420,000
Utah Copper Division	Garfield, Utah	1,000,000
Phelps Dodge Corp.:		
Douglas Smelter	Douglas, Ariz.	875,000
Morenci Branch	Morenci, Ariz.	900,000
New Cornelia Branch	Ajo, Ariz.	300,000

[1]Produces fire-refined copper as well as blister.

Table continued on following page.

Company	Situation	Annual Capacity, Tons of Material (Input)
United States Metals Refining Co., a subsidiary of American Metal Climax, Inc.	Carteret, N.J.	130,000
TOTAL		8,704,000

Company	Situation	Annual Capacity, Tons of Copper (Output)
Calumet & Hecla Corp. Universal Oil Products Co.	Hubbell, Mich.[1]	30,000
Quincy Mining Co.	Hancock, Mich.	15,000
White Pine Copper Co.	White Pine, Mich.	90,000
TOTAL		135,000

[1] Idle

SOURCE: ABMS, *Yearbook, 1970*, p. 30.

Capacities for the three smelters listed below the dotted line are stated in terms of output instead of charge (input). In fact the limiting quantity is the charge capacity and output depends on the charge and on the percentage of copper contained in it. The charge capacity of the White Pine smelter is reported elsewhere as 300,000 tons. On the basis of the input and output capacities for White Pine one may guess the capacities of Hubbell and Hancock smelters to be 100,000 tons and

50,000 tons respectively. The total U.S. smelter capacity appears then to be 9,154,000 tons of charge.

According to ABMS data, smelter capacity has increased 3.1 percent since 1966. During this period smelter production of copper increased 14.4 percent implying an increase in smelter capacity utilization.

The distribution of smelter capacity among the states is as follows:

SMELTER CAPACITY BY STATES, 1970
(Short Tons)

	Number	Capacity	Percentage Capacity
Arizona	8	4,455,000	48.6
Utah	1	1,000,000	10.9
Montana	1	1,000,000	10.9
Washington	1	600,000	6.6
Texas	1	576,000	6.3
Michigan	3	450,000	4.9
New Mexico	1	400,000	4.4
Nevada	1	400,000	4.4
New Jersey	1	180,000	2.0
Tennessee	1	90,000	1.0
	19	9,151,000	100.0

Nearly half of the smelter capacity and 8 of the 19 copper smelters in the United States are located in Arizona. Two very large smelters, each accounting for 11 percent of the total capacity are the Anaconda smelters in Texas and the Kennecott smelter in Utah. Two ASARCO

smelters in Washington and Texas each account for 6 percent of total capacity.

Refining

In 1970, U.S. refiners produced 2,305,000 short tons of refined copper, of which 493,000 short tons were refined from secondary blister, or scrap. This total represented a 3 percent increase over 1969 and a 5 percent increase since 1965. The U.S. imports substantial amounts of blister. In the case of Chile, U.S. refiners used to import Chilean blister, refine it, and often export the refined copper to Europe. Whether or not this will continue is uncertain.

The domestic copper refiners are listed below with their respective capacities in short tons.

Electrolytic:	
The Anaconda Company	
Great Falls, Mont.	190,000
ASARCO	
Baltimore, Md.	318,000
Perth Amboy, N.J.	168,000
Tacoma, Wash.	156,000
Cerro Copper & Brass, Div. of Cerro Corp.	
St. Louis, Mo.	44,000
Inspiration Consolidated Copper	
Inspiration, Arizona	70,000
International Smelting and Refining Co.	
Raritan, Perth Amboy, N. J.	150,000
Kennecott Copper Corp.	
Garfield, Utah	186,000

Electrolytic (Continued):	
Kennecott Refining Corp.	
Anne Arundel County, Md.	276,000
Phelps Dodge Refining Corp.	
El Paso, Texas	420,000
Laurel Hill, L. I., N. Y.	155,000
United States Metlas Refining Co.,	
Carteret, N. J., a subsidiary of American Metal Climax, Inc.	175,000
Total Tank Capacity	2,308,000
Lake and Fire Refining:	
Calumet & Hecla Corp.	
Universal Oil Products Co. Hubbell, Mich.	30,000
Kennecott Copper Corp.	
Hurley, New Mexico	103,000
Phelps Dodge Refining Corp.	
El paso, Texas	25,000
Laurel Hill, L. I., N. Y.	20,000
Quincy Mining Co.	
Hancock, Mich.	15,000
United States Metals Refining Co.,	
Carteret, N. J., a subsidiary of American Metal Climax, Inc.	85,000
White Pine Copper Co.	
White Pine, Mich.	90,000
Total Lake and Fire Refined	368,000
Total Refined Copper Capacity	**2,676,000**

SOURCE: ABMS, *Yearbook, 1970*, p. 27.

These data indicate that U.S. copper refineries have been operating at 86 percent capacity during 1970, but estimates vary on both production and capacity.

The distribution of electrolytic refining capacity among the states is as follows:

ELECTROLYTIC REFINING CAPACITY BY STATES, 1970
(Short Tons)

	Number	Capacity	Percentage Capacity
Maryland	2	594,000	25.7
New Jersey	3	493,000	21.3
Texas	1	420,000	18.2
Montana	1	170,000	8.2
Utah	1	186,000	8.1
Washington	1	156,000	6.8
New York	1	155,000	6.7
Arizona	1	70,000	3.0
Missouri	1	44,000	1.9
	12	2,308,000	99.9

Lake and fire refining capacity of 368,000 tons per year is concentrated in Michigan where there are three refineries having 37 percent of this capacity.

Employment

Table 7-3 presents employment, general input cost statistics, and data on value added and value of shipments for aggregate production of U.S. smelters and refiners for the years 1958, 1963, and 1967. A major strike occurred in 1967 and data for that year are not

Table 7-3

GENERAL STATISTICS FOR

PRIMARY COPPER SMELTERS AND REFINERS: 1967, 1963, 1958

Item	1967[1]		1963		1958	
	Smelters	Refiners	Smelters	Refiners	Smelters	Refiners
Establishments .....number	15	17	17	16	18	13
All employees:						
Total.....1,000	5.0	6.6	5.3	9.7	6.1	8.6
Payroll..$ million	34.5	46.1	34.6	61.6	32.3	45.1
Production and related workers:						
Total.....1,000	4.0	5.2	4.5	8.2	5.2	7.2
Man-hours..millions	7.8	10.3	9.1	16.7	10.4	14.4
Wages....$ million	25.7	35.3	27.9	50.1	25.5	36.1
Value added by manufacture...do	130.8	131.8	126.3	159.2	76.5	89.7
Cost of materials, fuel, electricity, contract work, and resales.....do	460.2	474.8	538.7	431.3	345.8	347.4
Value of shipments.....do	587.6	596.5	653.6	591.8	417.8	445.6

[1]Value of shipments and other receipts of the Primary Copper Industry totaled $1,245 million. This amount included shipments of primary copper (primary products) valued at $1,049 million, shipments of other products (secondary products) valued at $103 million, and miscellaneous receipts (mainly toll smelting of materials owned by others) at $93 million.

SOURCE: *U.S. Census of Manufactures, 1967* and *1963*, U.S. Department of Commerce.

typical of usual conditions but later comparable data are not yet available.

The data show that total U.S. employment in smelting in 1967 was about 5,000, down slightly from the 1963 and 1958 figures. Employment in refining was about 6,600 in 1967, down from 8,000-10,000 in the earlier years. Direct labor costs were a very small fraction of the value of shipments, amounting to less than 10 percent for both smelting and refining. The costs of materials, energy and so forth are substantial, with this category accounting for about 80 percent of the value of shipments in 1967.

Production and employment data disaggregated to the state or regional level are usually only available for combined smelting and refining. Complete data are not available because of disclosure problems. The data presented in Table 7-4 show that the major smelting and refining states were Arizona, Utah, New Jersey and Maryland.

The Copper Producing Areas

Arizona

Arizona would probably be most affected by any copper production cutbacks. Over 50 percent of domestic copper mine production originates in Arizona, and 8 of the 16 U.S. operating primary smelters, which account for over one-half of domestic capacity, are located within the state.

Although copper mining and smelting accounts for less than 4 percent of total state employment (less

Table 7-4

PRIMARY COPPER GENERAL STATISTICS, 1967

Geographic Area	Establishments		All Employees		Number of Production Workers (Thousands)
	Total (number)	With 20 or More Employees	Number (Thousands)	Payroll ($ Million)	
Northeast Region	7	7	3.9	27.1	3.0
New York	2	1	500-999	(D)	(D)
New Jersey	4	4	72,500	(D)	(D)
Pennsylvania	1	1	<250	(D)	(D)
North Central Region	3	3	0.5	2.9	0.4
Illinois	1	1	<250	(D)	(D)
Michigan	2	2	250-499	(D)	(D)
South Region	5	5	2.1	15.2	1.7
Maryland	2	2	1000-2499	(D)	(D)
Texas	2	2	500-999	(D)	(D)
West Region	17	17	5.2	35.3	4.1
Montana	2	2	1000-2499	(D)	(D)
New Mexico	2	2	250	(D)	(D)
Arizona	8	8	1000-2499	(D)	(D)
Utah	2	2	1000-2499	(D)	(D)
Nevada	1	1	250-499	(D)	(D)
Washington	2	2	500-999	(D)	(D)

(D) Withheld to avoid disclosing figures for individual companies.

SOURCE: *1967 Census of Manufactures*, U.S. Department of Commerce, Bureau of the Census, p. 33C-10.

than 25,000 of over 635,000), it supplies Arizona with one of its largest sources of income. Mining output alone, of which copper mining constitutes over 90 percent, is the second largest source of income, totaling $859,500,000 in 1969.[1]

Employment data of the state's copper smelters are difficult to obtain because many smelter employees are listed under "copper mining." However, the available data indicate that Arizona smelters employed between 2,500-3,500 people in 1970.[2]

Wages paid to Arizona copper mining and smelting employees totaled $201,665,000 in 1970.[3] This represents 7.2 percent of the wages earned by Arizona employees in industries covered by social security, a category that excludes agriculture. The copper industry's influence on the state, however, is much greater than these data indicate. The industry is one of the largest consumers of the construction and transportation industry, and, in its position as the state's second largest basic industry, it has a great effect on the state's nonbasic industries, such as retail trade and services.

Copper mines are scattered throughout the state. They are served by eight smelters located in five counties. Five of the smelters are situated in two adjoining counties, Gila and Pinal, which contain only 5.5 percent of the state's population.[4]

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[1] *Arizona Basic Economic and Manpower Data*, Arizona State Employment Service, September 1970, p. 2.

[2] *Copper Industry*, Arizona Department of Mineral Resources, September 1971, p. 38.

[3] *Ibid.*

[4] *Arizona Basic Economic and Manpower Data, op. cit.*, p. 3.

The copper industry forms the base of the economy of the Gila County. Mineral production was valued at $61,250,000 in 1968, and the copper mining industry provides employment for about one-third of the county.[1] In addition, "declines or upswings in the retail trade and other industry categories are dependent upon actions in the mining industry."[2]

Three firms operate smelters in the Gila County: ASARCO and Kennecott, both at Hayden, and Inspiration, at Miami. The total charge capacity of these three smelters is 1,830,000 tons per year, approximately 21 percent of U.S. primary smelter capacity.

The population of Hayden, Arizona was 1,276 in 1970, implying that almost all of the town's work force is employed at its two smelters.[3] Miami's population of 3,302 is somewhat larger, and the population of Gila County is 28,400.[4] All three smelters, however, are located within 10 miles of the Pinal County border; therefore, some of the smelters' employees may commute from the latter county.

The annual average labor force in Gila County was 8,575 in 1969, and the unemployment rate was 3.4 percent.[5] The unemployment rate is probably somewhat larger today. The general level of unemployment in Arizona increased to 5 percent in 1970 in line with nationwide trends. Of more direct interest, ASARCO has curtailed its production and has placed its customers on a quota system, affecting both smelting and mining employment.

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[1],[2],[3],[4],[5] *Ibid.*, pp. 20-21.

Pinal County also relies on the copper industry for its economic base. Its regional economy, however, is somewhat more diversified than Gila County's. Magma Copper Company (Newmont Mining Company) presently operates two smelters in the county, one at San Manuel and the other at Superior. Newmont has announced plans to shut down its plant at Superior and enlarge its San Manuel facility.[1] As these two towns are located at opposite ends of the county, the workers at the former plant will either have to move or find new employment, while the San Manuel plant will probably hire new workers.

The population of Pinal County was 68,000 in 1970; the 1969 civilian labor force averaged 22,300 while the unemployment rate was 2.6 percent. The populations of San Manuel and Superior were 4,524 and 4,875, respectively, in 1960.[2]

Newmont gave pollution control costs as the reason for its decision to limit the expansion of its San Manuel plant and shut down the Superior smelter.[3] This decision would seem to deprive the county of additional income, but shortages of labor do exist in Pinal County, generally among skill trades, professional workers, and higher level clerical workers.[4]

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[1] *Engineering & Mining Journal*, July 1971, p. 70.

[2] Arizona State Employment Service, *op. cit.*, p. 48.

[3] "Pressures build for more sulfur control," *Metals Week*, June 21, 1971, pp. 25-26.

[4] Arizona State Employment Service, *op. cit.*, p. 48.

Phelps Dodge's mine-mill-smelter complex at Morenci is the crux of Greenlee County's economy. The mine itself spends $68 million annually in the county, and 90 percent of the business payroll comes from the mines.[1] In 1969 the annual average civilian labor force in the county numbered 4,150 (1970 population being 10,108), and the unemployment rate was 2.4 percent.[2]

Phelps Dodge's smallest smelter is at Ajo in Pima County, the second largest county in the state with a 1970 population of 345,000. The smelter and its mining customers do not seem to be crucial elements of the county's economy. Tucson, the largest city, is a small metropolis featuring a very diversified economy. Agriculture and the government are also large employment sectors.

In 1969 Pima's unemployment rate was 3.1 percent out of a civilian labor force of 117,200.[3]

Phelps Dodge has announced that it will be forced to close its Douglas smelter if pollution legislation is not relaxed.[4] Having an annual charge capacity of 875,000 tons, this smelter alone accounts for over 10 percent of U.S. primary smelter capacity. Its closing would have serious effects on the regional economy. It should be noted, however, that Phelps Dodge's decision to shut down was probably not based entirely on pollution considerations. The company had already decided to close

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[1] *Ibid.*, p. 27.

[2] *Ibid.*, p. 28.

[3] *Ibid.*, p. 44-45.

[4] "Closure of Big Douglas Copper Smelter Would Raise Havoc in Many Quarters," *Pay Dirt*, October 25, 1971, p. 3.

its mine at Bisbee by 1973, thereby discontinuing an important source of ores.[1]

If it closes the plant, Phelps Dodge plans to discontinue its custom smelting and treat only its own ores at its remaining two smelters.[2] If this occurs, however, several mines in the area will have no place nearby to smelt their copper and may curtail production.

The Douglas smelter employs 645 persons and maintains a payroll of $6 million.[3] Its closure would undoubtedly disrupt the city of Douglas, whose population is 12,300.[4]

Copper mining is extensive throughout Arizona, and is important in other areas as well as those mentioned above. The economies of Graham, Mohave, Yavapai, and Yuma Counties rely heavily on copper mining. It is also worth noting that the county unemployment statistics quoted above are for 1969 and are likely to be considerably higher today. Total unemployment within the state increased from 3.1 percent in 1969 to 5.3 percent (seasonally adjusted) in June 1970.[5,6]

The Other Copper Smelting States

Ten primary copper smelters are located in Montana, Texas, Tennessee, Utah, New Mexico, Nevada, Michigan, and

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[1] Arizona State Employment Service, *op. cit.*, p. 12.

[2] *Pay Dirt*, *op. cit.*, p. 3.

[3] *Ibid.*, p. 6.

[4] Arizona State Employment Service, *op. cit.*, p. 13.

[5] *Ibid.*, p. 2.

[6] *Manpower Report of the President*, U.S. Department of Labor Statistics, April 1971, p. 271.

Washington. Employment data for these smelters are listed in Table 7-5, by state and, when applicable, by Standard Metropolitan Statistical Area (SMSA). Although these data are not very detailed or informative for our purposes, it appears that the smelters are probably the main sources of employment for the towns in which they are located, with two exceptions: El Paso, Texas and Tacoma, Washington.

ASARCO has indicated that it will close its Tacoma smelter unless the area pollution control laws are modified.[1] Although employment data for the copper smelter are unavailable, it probably totals around 500. As the total employment of the Tacoma SMSA is over 100,000, the closing of the smelter would have only a small direct impact on the regional economy. Little of the ores smelted at Tacoma are mined in Washington. If the smelter closes, and another does not open to replace it, the Canadian and Arizona mines which normally supply the smelter could be adversely affected.

Copper Range's smelter at White Pine, Michigan may also close if 90 percent of its sulfur feed must be eliminated.[2] The smelter is unique in that the ore it processes has a comparatively low sulfur content. It seems that the low sulfur content makes the recovery of 90 percent of its sulfur feed difficult and costly. If the smelter closes, the mines supplying it might also shut down, to the severe detriment of the local economy.

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[1] "SO_2 Laws Force U.S. Copper Smelters into Industrial Russian Roulette," *Engineering & Mining Journal*, July 1971.

[2] *Ibid.*

Table 7-5

EMPLOYMENT STATISTICS FOR PRIMARY SMELTER LOCATIONS

(Except Arizona Smelters)

	Total Employment (Thousands) April, 1971[1]	Mining Employment (Thousands) April, 1971[1]	Prim. Non-Fer. Emp. 1960[2]	Percent Unemployment State-1970[3] SMSA-1969[4]	Population 1960[5]
Nevada	204.5	3.9	1,361	5.4	
McGill					2,200
Montana	198.9	6.7	4,765	5.4	
Anaconda					12,090
Michigan	2949.6	12.4	19,758	7.0	
White Pine					1,000
New Mexico	293.3	16.5	233	6.3	
Hurley					1,850
Tennessee	1346.9	7.3	7,086	4.4	
Copperhill					630
Texas	3630.0	103.1	9,783	3.5	
El Paso SMSA	103.7		1,476	3.7	
(El Paso)					227,000
Utah	367.2	12.8	2,179	5.9	
Garfield					N.A.
Washington	1040.3	1.6		8.3	
Tacoma SMSA	104.4	N.A.	1,145	5.0	
(Tacoma)					150,000

Data Sources on following page.

Table 7-5 (Continued)
EMPLOYMENT STATISTICS FOR PRIMARY SMELTER LOCATIONS
(Except Arizona Smelters)

DATA SOURCES:

[1] *Employment and Earnings*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 18, No. 1, July, 1971, Table B-7.

[2] *1960 Census of Population Detailed Characteristics of the Population*, Tables 126-127.

[3] *Manpower Report of the President*, U.S. Department of Labor Statistics, April, 1971.

[4] *1970 Statistical Abstract of the United States*, U.S. Department of Commerce, Bureau of the Census, 1970, Section 33, Table 1.

[5] *Hammond's Ambassador World Atlas*, C. S. Hammond and Company, 1964, Maplewood, N. J.

Financial Performance of the U.S. Copper Industry

Table 7-6 shows the net sales, operating and net incomes, and returns on net sales, and stockholders' equity for the major U.S. copper producers. Cities Service is omitted because its copper operations are only a small portion of its total operations.

The data show that these firms are generally large in relation to the size distribution of U.S. corporations and have sales on the order of $.5 to $1 billion per year. The data are for combined operations rather than for copper operations only. Thus, for the custom smelters, especially AMAX, the earnings figures include sizeable earnings from sales of metals other than copper. AMAX is the world's major producer of molybdenum, which seems to be a highly profitable industry, so its returns from copper operations may be somewhat lower than those shown in the table.

It appears from the data that in 1968 and 1969 the firms earned a minimum of 8 percent or more on stockholders' equity. If Anaconda is disregarded, the lowest ratios of net income/equity were 10 percent for Cerro in 1968 and 10.9 for Kennecott. Some firms have had very high returns on equity. Inspiration returned 24 percent in 1969 and 27 percent in 1970, and Newmont returned 23 percent in 1968, 24 percent in 1969 and 1970. For three firms, figures for 1970 were rather poorer for 1970 than for 1968 and 1969. Anaconda and Cerro each had net income equal to 5.4 percent of equity. Copper Range had 8.9 percent as against 11.5 percent in 1968

Table 7-6

FINANCIAL PERFORMANCE OF THE MAJOR COPPER PRODUCERS[1]

	Net Sales (N.S.)	Stock-Holders Equity (S.E.)	Operating[2] Income (O.I.)	Net Income[3] After Taxes (N.I.)	O.I. / N.S. Percent	O.I. / S.E. Percent	N.I. / N.S. Percent	N.I. / S.E. Percent
AMAX								
1968	570.6	455.2	N.A.	67.4	--	--	11.8	14.8
1969	753.5	553.1	N.A.	69.1	--	--	9.2	12.5
1970	840.7	609.8	N.A.	83.6	--	--	9.9	13.7
Anaconda[4]								
1968	1051.0	1114.8	253.5	89.0	24.1	22.7	8.5	8.0
1969	1410.6	1166.2	393.1	99.3	27.9	33.7	7.0	8.5
1970	977.4	1188.4	108.9	63.8[5]	11.1	9.2	6.5	5.4
ASARCO								
1968	634.1[6]	587.1	38.1	73.2[7]	6.0	6.5	11.5	12.5
1969	771.0	640.7	60.1	99.4	7.8	9.4	12.9	15.5
1970	717.8	676.6	57.5	88.8	8.0	8.5	12.4	13.1
Cerro								
1968	431.0	311.1	N.A.	31.0	--	--	7.2	10.0
1969	498.9	339.4	N.A.	40.0	--	--	8.0	11.8
1970	490.6	343.4	N.A.	18.6	--	--	3.8	5.4
Copper Range								
1968	82.1	84.6	20.0	9.7	24.4	23.6	11.8	11.5
1969	102.3	99.5	27.9	15.9	27.3	28.0	15.5	16.0
1970	97.5	108.1	21.9	9.6	22.5	20.3	9.8	8.9

Table 7-6 (Continued)

	Net Sales (N.S.)	Stock Holders Equity (S.E.)	Operating Income (O.I.)	Net Income After Taxes (N.I.)	O.I./N.S. Percent	O.I./S.E. Percent	N.I./N.S. Percent	N.I./S.E. Percent
Inspiration								
1968	43.9[8]	49.3	8.7	5.7	19.8	17.6	13.0	11.6
1969	69.5	55.8	22.5	13.4	32.4	40.3	19.3	24.0
1970	88.8	65.8	30.5	17.8	34.3	46.4	20.0	27.1
Kennecott								
1968	724.5[9]	1022.3	171.9	111.2	23.7	16.8	15.3	10.9
1969	1050.0	1108.2	286.9	165.4	27.3	25.9	15.8	14.9
1970	1133.1	1172.8	322.3	150.9[10]	28.4	27.5	13.3	12.9
Newmont[14]								
1968	59.3[11]	221.4[13]	N.A.	50.3[12]	--	--	84.8	22.7
1969	197.0	267.7	N.A.	64.1	--	--	32.5	23.9
1970	214.8	314.7	N.A.	75.2	--	--	35.0	23.9
Phelps Dodge								
1968	550.4	538.2	98.1	64.1	17.8	18.2	11.6	11.9
1969	672.1	588.3	138.4	89.4	20.6	23.5	13.3	15.2
1970	775.3	656.2	188.0	107.8	24.2	28.6	13.9	16.4

SOURCES: Standard and Poor's *Industrial Surveys*, September 16, 1971, Section 2: Basic Analysis, pp. M130-M132.
Stockholder's Equity figures obtained from individual company annual reports.
All data for Cerro-AMAX collected from annual reports.

Table 7-6 (Continued)

Footnote:

[1]Expressed in millions of dollars

[2]Before depreciation

[3]Before depletion

[4]Chilean properties excluded from balance sheet after 1968 (except as investment) and excluded from income statistics after 1969.

[5]Includes extraordinary charge of 4.3 million dollars

[6]Includes service revenues in all years

[7]After depletion in all years

[8]Total operating revenues in all years

[9]Total operating revenues in all years

[10]Includes extraordinary charge of 34.2 million dollars

[11]Gross revenues in all years including profit and losses on securities, etc. prior to 1969

[12]Includes in 1968 equity in undistributed earnings (losses) of companies 50 percent or more owned

[13]Figures include retained earnings plus book value of stock

[14]Magma Copper Company is a wholly owned subsidiary of Newmont Mining Company

and 16.0 percent in 1969. Otherwise, the firms appear to have performed as well in 1970 as in the previous two years. Anaconda's poor performance is attributable, at least in part, to the loss of its Chilean properties. Kennecott, however, had a profitable year despite the expropriation of its Chilean properties which comprised only a relatively small part of its Holdings.

This is one of four reports prepared by
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Copper
Lead
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